Fast and efficient liver imaging with Primovist®/Eovist®

Thomas Lamprecht[1, 2]; Martin Rohrer, Ph.D.[2]; Gregor Thörmer, Ph.D.[1]

[1] Siemens Healthineers, Erlangen, Germany
[2] Bayer AG, Radiology, Berlin, Germany

Introduction

Primovist[1] is a dedicated contrast agent for MR imaging of the liver. It combines the dynamic characteristics of an extracellular contrast agent with characteristics for liver-specific imaging during the hepatobiliary phase [1, 2]. Primovist contains an ionic, highly water-soluble Gd3+ chelate complex and therefore has magnetic properties comparable to other gadolinium-containing contrast media that are used to enhance dynamic T1-weighted imaging [3]. The addition of a lipophilic EOB group increases protein binding in plasma and maximizes

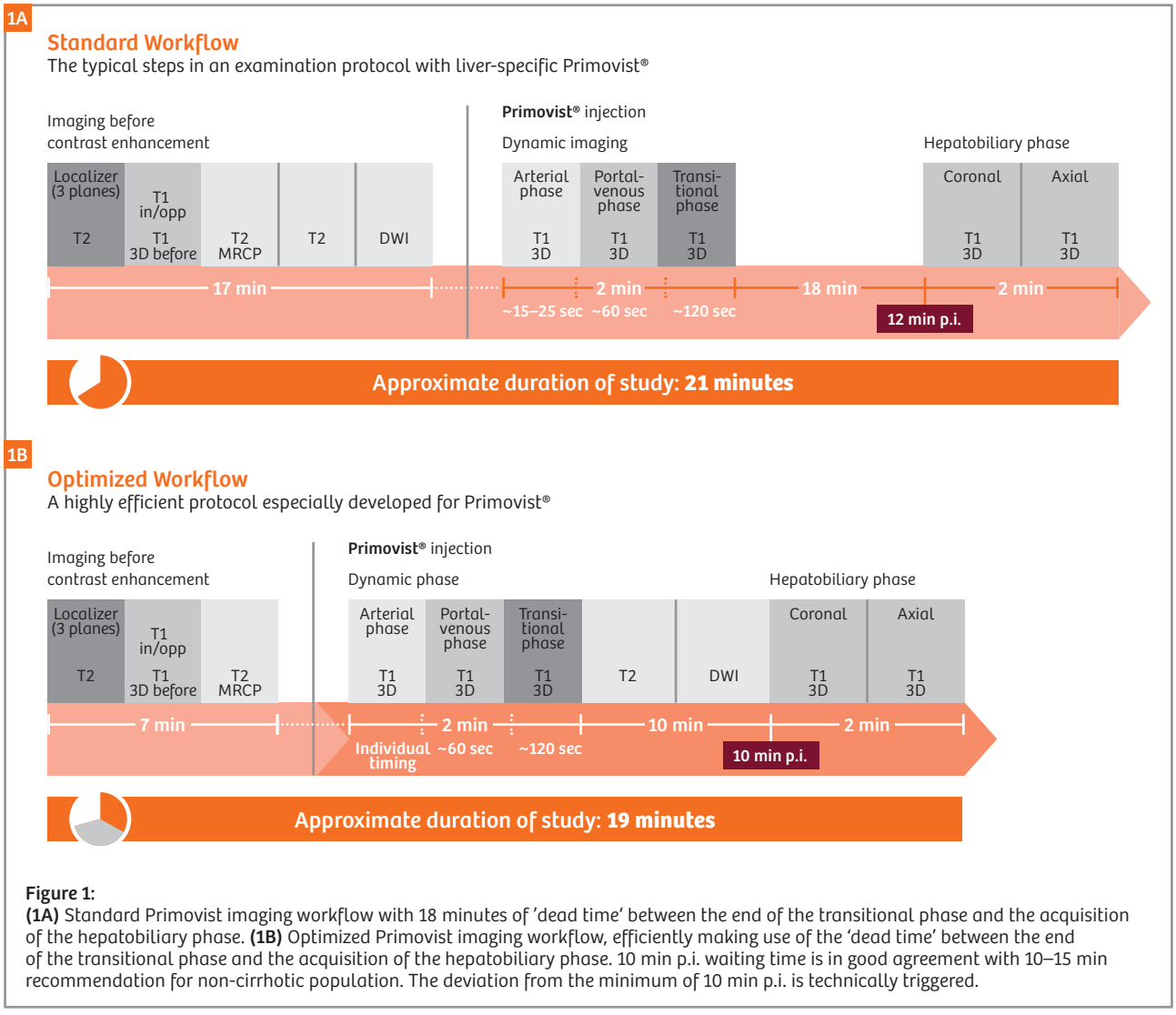


Figure 1:
(1A) Standard Primovist imaging workflow with 18 minutes of 'dead time' between the end of the transitional phase and the acquisition of the hepatobiliary phase. **(1B)** Optimized Primovist imaging workflow, efficiently making use of the 'dead time' between the end of the transitional phase and the acquisition of the hepatobiliary phase. 10 min p.i. waiting time is in good agreement with 10–15 min recommendation for non-cirrhotic population. The deviation from the minimum of 10 min p.i. is technically triggered.

Figure 1 is courtesy of: Elmar M. Merkle, Department of Radiology, Basel University Medical Center, Basel, Switzerland.

contrast medium uptake by the hepatocytes. Once injected, Primovist is taken up by functional hepatocytes, which means that the contrast medium accumulates in the cells. After administration, the signal enhancement in healthy liver tissue is present for at least two hours. Since malignant tumors and non-hepatic tissues (e.g., metastases) possess very few functional hepatocytes, or none at all, they exhibit almost no Primovist uptake. This results in a pronounced contrast between malignancy (dark = hypointense) and adjacent healthy liver tissue (bright = hyperintense). Compared with healthy tissue, benign liver lesions may display an even more pronounced signal enhancement [4].

Since the recommended minimal waiting time of approximately 10 to 15 minutes (for non-cirrhotic population) between contrast media administration and the acquisition of hepatobiliary phase images is relatively short, examinations using Primovist make it possible to avoid taking the patient off the MR table, waiting until contrast accumulates in the hepatocytes, and rescheduling the patient for an additional late-phase scan. Nonetheless, the unused waiting time is still perceived as 'dead time', inevitably resulting in long exam slots (see Figure 1A).

A time-optimized workflow for Primovist liver MRI

In order to make better, effective use of the time between the dynamic and liver-specific phases, it is highly desirable to

A. shift the time-intensive acquisition of high-resolution T2-weighted images and diffusion-weighted images to after the contrast injection, and

B. shorten the delay between contrast dynamics and the acquisition of hepatobiliary phase images.

With this in mind, respective studies have been undertaken which show that Primovist does not have any significant impact on the signal of the liver parenchyma in T2-weighted [5] or diffusion-weighted sequences [6]. Furthermore, a fairly marked liver-specific contrast enhancement will already be present after 10 minutes in patients without liver cirrhosis. This will only increase slightly up to 20 minutes after contrast injection [7]. Accordingly, Bayer has suggested a shortened Primovist imaging protocol which allows performing a complete Primovist examination in a 30-minute exam slot (Fig. 1B).

In this article, we present three optimized workflows for efficient imaging with Primovist:

- Two standard strategies without additional license requirements
- One strategy using advanced Abdomen Dot Engine features such as automated slice positioning, auto coverage, and ABLE[2] for personalized timing of the arterial phase thanks to automated bolus detection, and automated adjustment of breath-hold times to individual patient capabilities.

Respective protocols for the 1.5T and 3T platforms are available to download on the MAGNETOM World website at **www.siemens.com/magnetom-world > Clinical Corner > Protocols**.

Primovist standard protocols

The standard protocol set for liver imaging with Primovist provides two different strategies: The default imaging strategy uses automated breath-hold commands during exhalation, while the alternative strategy uses breath-hold commands during inhalation. Before starting the actual examination, users can decide on the exam strategy (see Figure 2). Depending on this decision, respective protocols are automatically pulled into the exam queue. Figure 3 illustrates the flow of the two different strategies. The default strategy deliberately uses exhalation. Even though patients perceive breath-holding during exhalation to be more demanding, the literature shows that the stability and reproducibility is higher [8]. In addition, planning images can be used throughout the entire exam for both breath-hold and free-breathing acquisitions. The alternative strategy using inhalation includes additional planning images, since the free-breathing and triggered exams (T2-weighted and diffusion-weighted) should not be planned on images acquired during inhalation (see Figure 4).

The actual exam starts with the acquisition of localizer images. These are followed by fast overview scans with a single-shot T2 HASTE technique in coronal and axial orientation. If preferred, T2 BLADE scans may be used instead of a breath-hold T2 HASTE approach. Depending

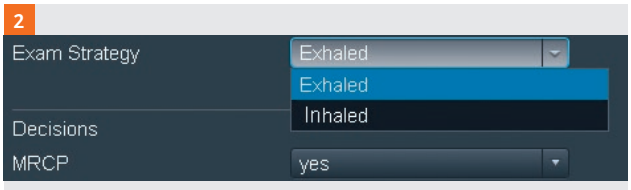


Figure 2:
Prior to the exam, users can choose the strategy from the dialog box. In this step, they can also decide whether the individual clinical question requires a fast T2-weighted MRCP.

[1] 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.

[2] Automated Breath-hold Liver Exam

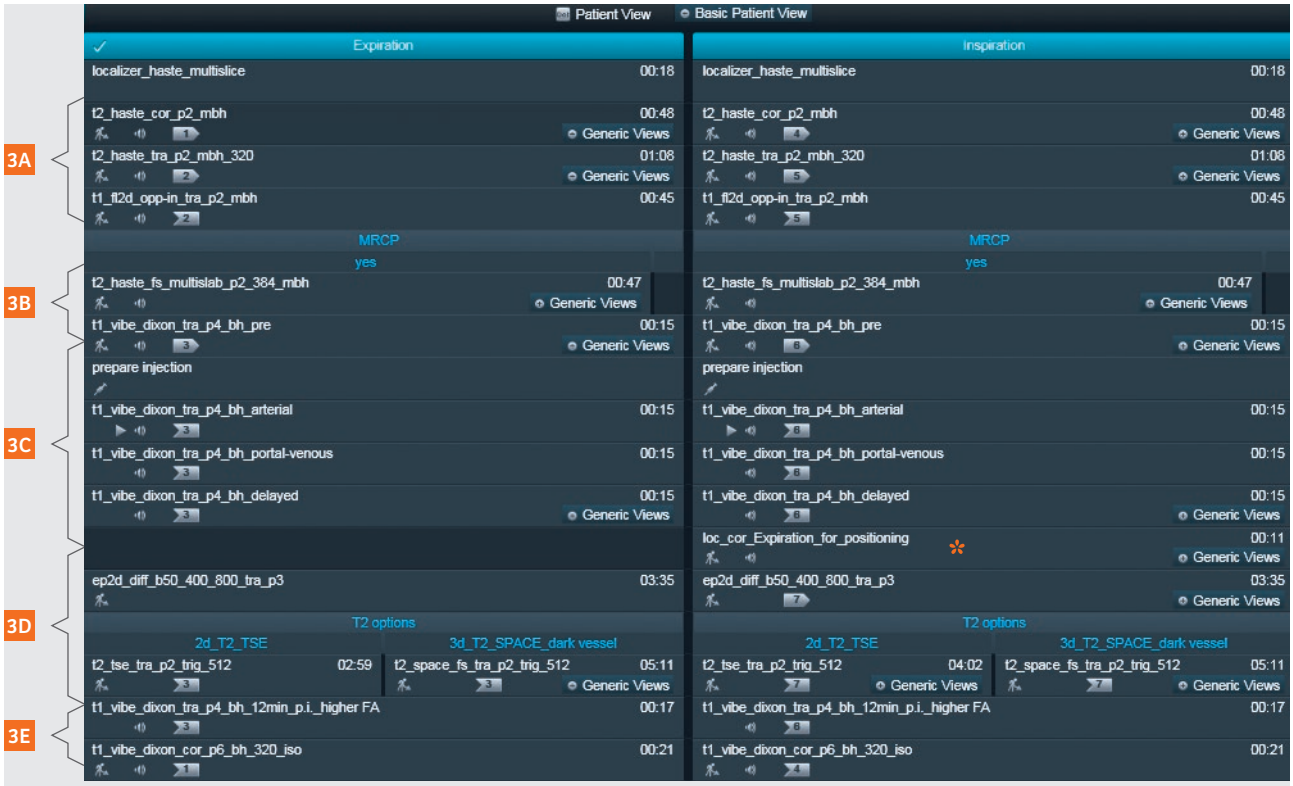


Figure 3:
Two standard strategies using exhalation and inhalation are provided. **(3A)** Fast planning images acquired with coronal HASTE and transversal HASTE FS scans provide an overview. **(3B)** Optional fast thick-slab HASTE FS scans for T2-weighted MRCP follow. **(3C)** Contrast dynamics; **(3D)** DWI and T2 (2D or 3D) post-contrast; **(3E)** delayed imaging in different planes.
(*) In the inhalation strategy, additional planning images are required to position the free-breathing scans correctly.

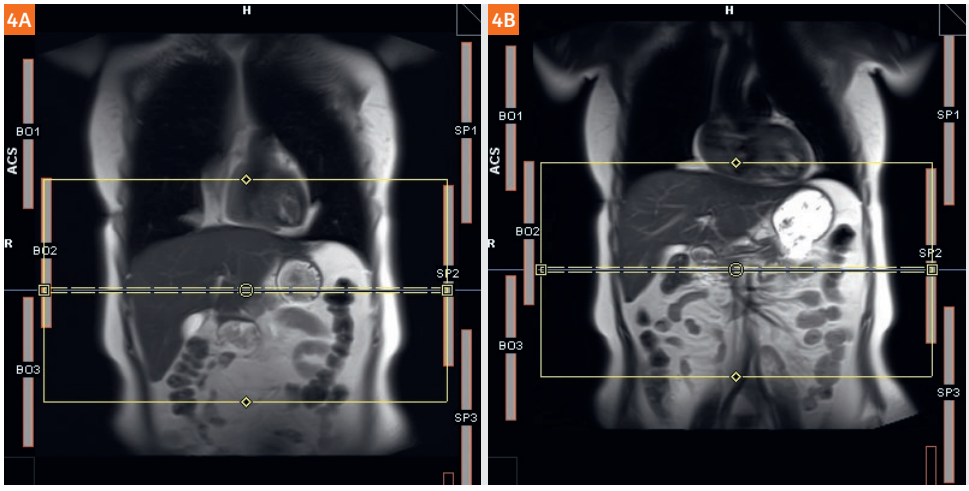


Figure 4:
Inhaled **(4A)** and exhaled **(4B)** coronal planning images illustrate how significantly the organ coverage is affected: While the liver is perfectly centered in the FOV in the inhaled exam, the liver dome risks being cut off in images acquired with triggering, which is typically performed in the exhaled phase. Therefore, an additional localizer is provided to ensure consistent planning of the free-breathing and triggered scans.

on individual preferences, *strongly* T1-weighted in-phase and opposed-phase scans can be acquired with a 2D FLASH technique. This information, however, is also included in the T1-weighted 3D VIBE scans prior to contrast administration and can therefore be skipped if acceptable in the specific clinical setting. Throughout the entire exam, users receive guidance on how to plan and execute the subsequent scans, such as the optional multiple T2-weighted MRCP scans with a thick-slab 2D HASTE in rotating acquisition (see Figure 5).

For the contrast-enhanced scans, the protocols are prepared so that the system automatically issues breath-hold commands and adheres to typical delays between the different phases. The delay between the phases can

Figure 5:
Overview of the scanner's user interface. Planning images are displayed at the top of the screen, the scan queue is displayed in the lower left, and guidance on how to perform subsequent scans is provided in the "Guidance" window in the lower right of the screen. If "Coupled Graphics = On" is selected, users can intuitively plan five thick-slab MRCP scans with T2 HASTE by positioning the center of the slice stack in an image showing the common bile duct.

be adapted to the institution's individual needs. Important information regarding timing of the contrast-enhanced scans can be found in Figure 6. Depending on local availability and institutional preference, contrast can be delivered via an automated injector.

After starting the contrast injection and imaging countdown simultaneously, arterial, portal-venous and delayed phase imaging will be performed automatically with predefined pauses which can be adapted to the institution's own standards. If desired, subtraction images of the different phases can be automatically generated. As proposed by Bayer, the time between the delayed phase and the hepatobiliary phase can be effectively used to acquire high-resolution T2-weighted and diffusion-weighted images in free-breathing. Users can choose between 2D or 3D acquisition for the T2-weighted scans. The 3D T2-weighted scans also include weak "diffusion" gradients to generate a dark-vessel contrast in the liver, which makes it easier to identify T2-intense lesions.

Approximately 10 to 15 minutes post contrast injection, the hepatobiliary phase scans can be started in non-cirrhotic patients. According to the recommendations in the literature, the flip angle is increased for higher contrast between enhancing normal liver parenchyma and non-enhancing lesions. At the end of the exam, an optional T1-weighted MR cholangiography with a high-resolution FLASH 3D protocol in one breath-hold can be acquired. This scan provides a nice functional overview of the biliary system (post-resection, for example), as Primovist is excreted by 50% via the hepatobiliary system).

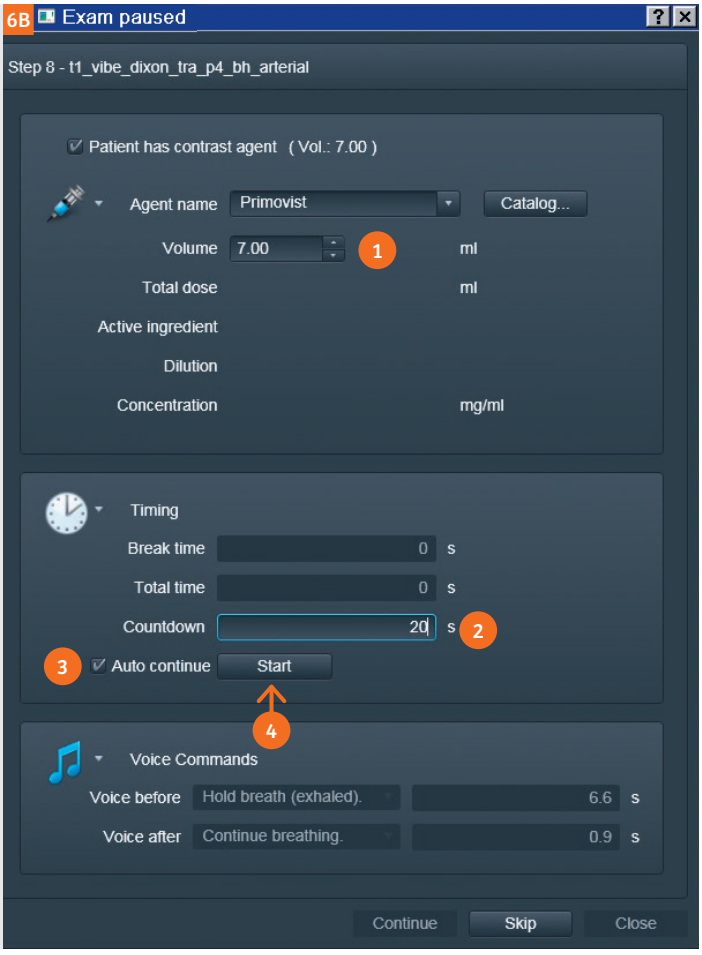


Figure 6:
(6A) After acquisition of the pre-contrast T1-weighted scans (#6 in the queue), the examination is stopped to prepare the injector and to check the coverage and quality of the pre-contrast scans (#7). If everything is fine, users can proceed to the next step (#8) since the arterial phase imaging will not start yet ("play" symbol in the queue). A dialog box **(6B)** will open automatically and allow users to define the contrast media and contrast volume (1). In the "Timing" section, users set the delay (2) between contrast administration and start of arterial phase imaging. A typical value is 20 seconds. If "Auto continue" (3) is selected, users can start the countdown by pressing "Start" (4) and administer contrast agent at exactly the same time. In this case, the MR system will automatically count down to zero and will also issue the breath-hold commands in a good time to ensure that the scan starts when it reaches zero. When "Auto Continue" is selected, users should not press "Continue" or "Skip".

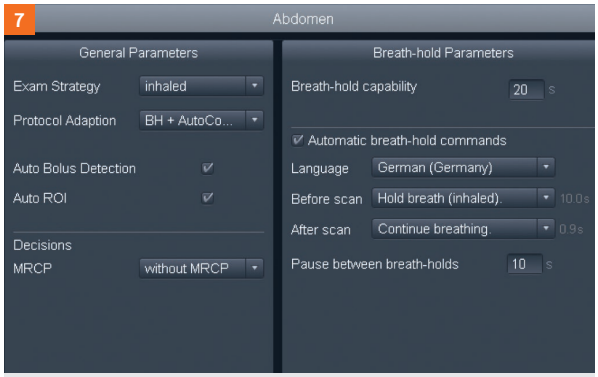


Figure 7:
Prior to the actual examination, users can tailor the exam to the individual patient characteristics and clinical question, e.g., by setting the maximum breath-hold duration and using Auto Bolus Detection for individualized arterial phase imaging, as recommended by Bayer for imaging with Primovist.

Primovist protocol using Abdomen Dot Engine features[3]

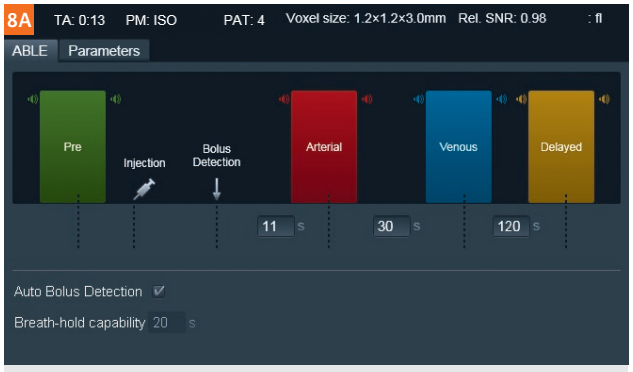
The Primovist Abdomen Dot Engine strategy follows exactly the same structure and logic as the standard protocols: Coronal and axial HASTE scans, 2D in-phase and opposed-phase FLASH, and optional fast T2-weighted MRCP scans prior to contrast are followed by dynamic contrast-enhanced scans and high-resolution T2-weighted, diffusion-weighted, and hepatobiliary phase imaging. The original, general Abdomen Dot Engine settings with breath-holds during inhalation remained unchanged. If desired, users can change this general approach. Additional features and related advantages of the Abdomen Dot Engine are as follows:

- The exam can be tailored to the patient's individual breath-hold capabilities by simply defining the maximum breath-hold duration at the beginning of the exam or by changing it during the exam. The software automatically adapts related imaging parameters in a consistent way.
- Automated landmark detection in the abdomen (organ box) allows automated adaptation of the field-of-view

[3] A prerequisite for using this strategy is the local availability of the Abdomen Dot Engine license. TWIST-VIBE and GRASP-VIBE are licensed options and not available for all systems.

and number of slices, and correct positioning of the imaging volume in the individual anatomy (see Figure 7).

- Auto Bolus Detection with ABLE (see Figure 8) precisely adapts the start (respecting also TTC) of the arterial phase scans to the patient's physiology by releasing the scan when contrast agent arrives in the ROI in the descending aorta. The location of the ROI can either be defined by the user or automatically by the software (Auto ROI).
- Encapsulated acquisition is possible for double-echo T2-weighted scans with "normal" (TE = 70 ms) and "very strong" (TE = 430 ms) T2-weighting between venous and delayed scans.



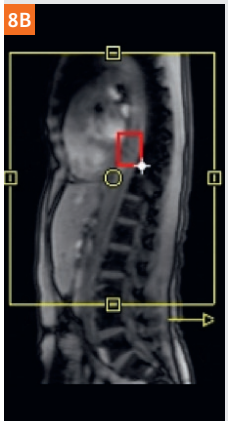


Figure 8:
(8A) The progress of dynamic imaging is intuitively displayed, and it is easy to modify pauses between the different phases. **(8B)** To perfectly catch the early arterial enhancement in the liver, a ROI is automatically (or manually) placed above the descending aorta. As soon as a signal threshold in this region is exceeded, the subsequent T1-weighted VIBE is released and dynamic phase imaging starts without further user interaction. Automatic breath-hold commands are included. If preferred, the CareBolus scans can also be acquired in axial orientation.

- Automated subtraction of dynamic liver phases with a liver motion correction algorithm (DynaVIBE) ensures that slices from different breath-holds represent the same anatomical position.
- The system can seamlessly integrate multiple arterial phase images with TWIST-VIBE or free-breathing liver dynamics with GRASP-VIBE from the Abdomen Dot library.

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Contact

Gregor Thörmer, Ph.D.
Global Segment Manager MRI in Oncology
Siemens Healthineers
Phone: +49 (0)9131 84-7726
gregor.thoermer@siemens-healthineers.com