How I do it: Non Contrast-Enhanced MR Angiography (*syngo* NATIVE)

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Introduction

The realization that the administration of gadolinium-based contrast agents may be a factor in the development of Nephrogenic Systemic Fibrosis (NSF) in patients with renal failure has created a renewed interest in the in angiographic methods using intrinsic rather than extrinsic contrast mechanisms. The current economic climate in the Healtcare industry means that there is an increasing need to develop more cost-effective methods and reduction of contrast agent utilization is one element which might contribute to this. The existing non contrast-enhanced sequences, such as the Time-of-Flight (TOF) sequence, have their advantages in regions like the intracranial vasculature, but may have limitations for abdominal or peripheral imaging.

syngo NATIVE was introduced with software version *syngo* MR B17. It comprises two different non-contrast MRA techniques:

- *syngo* NATIVE TrueFISP (optimized for the renal arteries)
- *syngo* NATIVE SPACE (optimized for peripheral regions)

Both applications use mechanisms for contrast generation which depend on physiological processes. In NATIVE TrueFISP the inflow of non-inverted blood is exploited to depict the vessels. In NATIVE SPACE the image contrast is based on the pulsatility of the blood flow. Hence, the methods might be limited (reduced or no contrast-to-noise-ratio (CNR)) for patients with severe pathologies that have a direct influence on these physiological processes. This article not only demonstrates how to plan and perform a *syngo* NATIVE examination, but also gives some hints and tricks in cases where it may be difficult to get good image quality.

A clear understanding of the technical background of these measurements gives the user the opportunity to adapt the scan parameters individually, with respect to the patient's physiology. The ability to tailor the measurement can maximize the success rate.

The theory behind *syngo* NATIVE TrueFISP

syngo NATIVE TrueFISP is based on the TrueFISP sequence which typically yields a bright blood signal.
To enhance the contrast between flowing and static magnetization, an inversion pulse is applied to the region of interest. When imaging takes place after an inversion time TI, when the magnetization of surrounding tissue is close to zero, the background will have low signal. During the TI, however, fresh blood, with no history of inversion, enters the inverted slab, and the filled vasculature appears bright. The higher the more blood volume entering the inverted region, the better the contrast and the assessment of the small branches of the vessels. Figure 1 shows the basic principle of *syngo* NATIVE TrueFISP. With *syngo* NATIVE TrueFISP, respiratory synchronization can be realized with the 1D PACE Navigator. In this case the images are usually acquired in end-expiration to prevent breathing artefacts. To increase the effectiveness and to reduce further artefacts from pulsatile vessels, you can combine 1D PACE with ECG-triggering. When a new inversion is played out with each ECG trigger signal,


1 Basic principles of *syngo* NATIVE TrueFISP
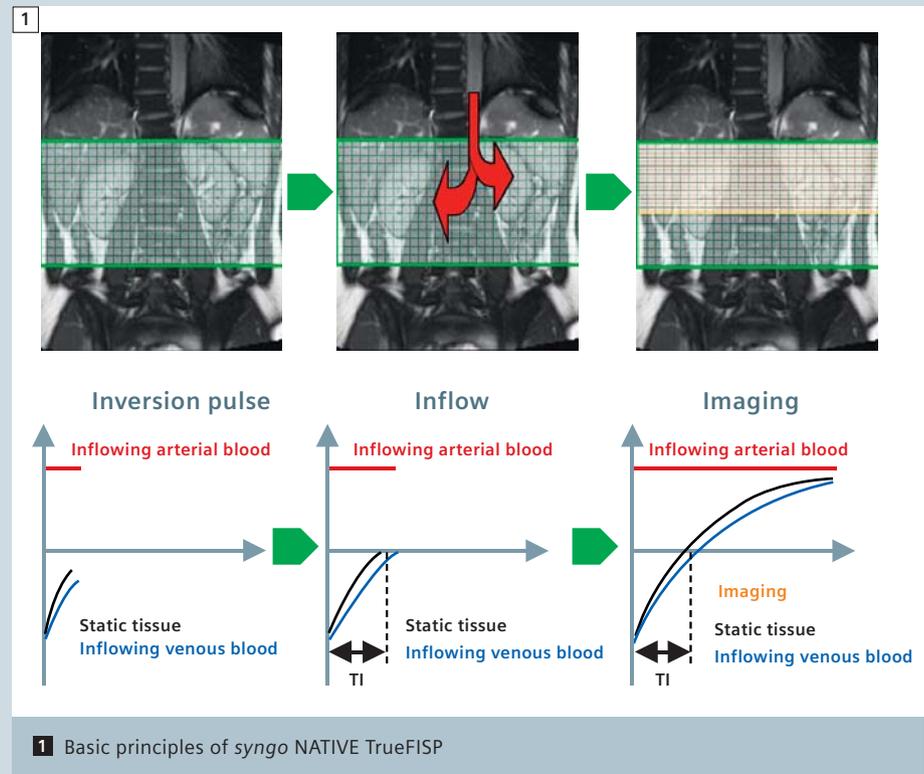
the total blood volume available for imaging is proportional to the stroke volume within one heartbeat.

Patient preparation

The patient is positioned supine, head or feet first.

It is highly recommended to use ECG-triggering. To reduce patient set-up time, *syngo* NATIVE TrueFISP data can be acquired without ECG triggering. If doing so it is necessary to ensure that the inversion time is long enough so that that there is sufficient inflow into the area of interest – with pulsatile flow if the TI chosen is too short (shorter than the RR interval of the patient) there is the likliehood that a significant proportion of the acquired data is acquired without capturing an inflow event. To reduce this likelihood set the TI to be long enough to always include an inflow episode (eg 1200 to 1400 ms). Remember that the volume of non-inverted blood has to be large enough to fill all the small vessel branches. Position the Body Matrix coil on the patient, so that both regions the kidneys and the diaphragm are covered. The respiratory gating is usually performed with the 1D PACE Navigator, alternatively the respiratory cushion can be used. All the protocols are set up in the reference mode. This is essential on the Siemens open bore systems MAGNETOM Espree and MAGNETOM Verio, to achieve a good signal-to-noise-ratio for the renal arteries and the navigator. Position the laser marker in the middle of the renal hilum and the dome of the diaphragm. On the MAGNETOM Avanto, the examination can also be performed in the isocenter since the FOV in z-Axis is 50 cm. With software version *syngo* MR B17, a new functionality regarding the ECG display has been introduced. The learning cycle is demonstrated with a count-up mechanism, to show when the necessary 10 heartbeats are covered. The learning phase reduces the likelihood of inappropriate trigger detection, for example from artefacts due to the magneto-hydrodynamic effect.

2 "Inversion" Subcard
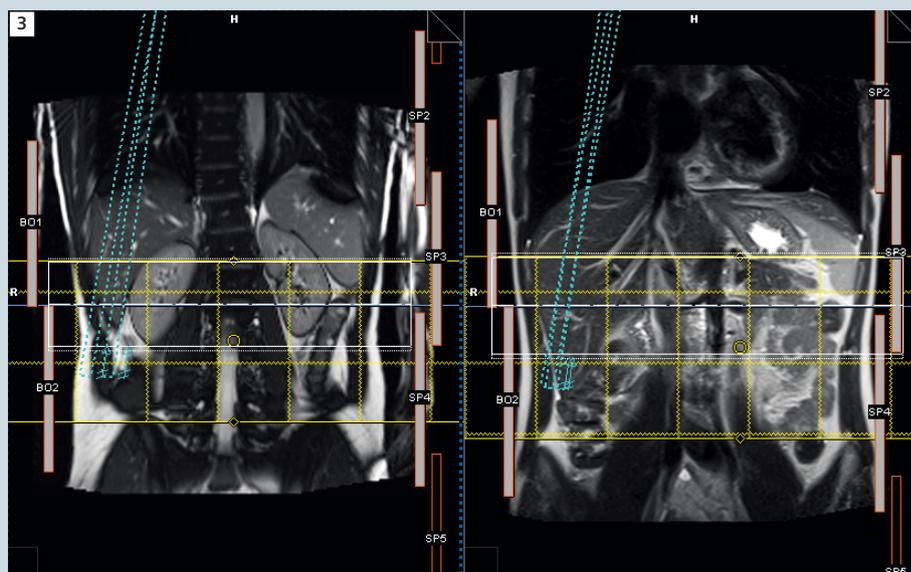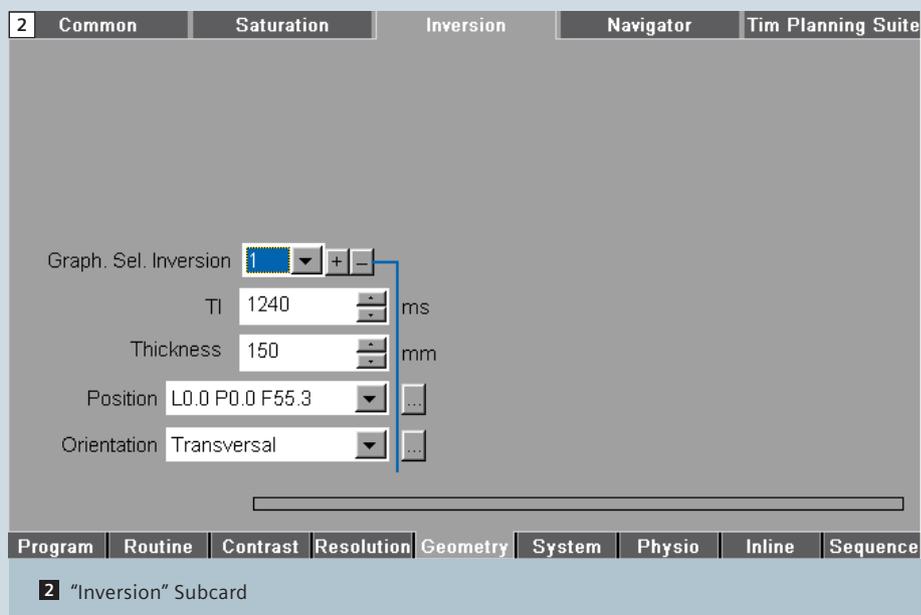
3 Coronal localizers. The TrueFISP localizer (left image) is standard in the protocol set-up, the HASTE sequence (right image) can be used alternatively.

Protocol set-up

The axial and coronal TrueFISP localizers are acquired as non-breath-hold examinations.

When opening the *syngo* NATIVE TrueFISP protocol, three graphical elements are shown, which have to be positioned correctly. We recommend to start with the navigator positioning, so that the center of the navigator is located at the dome of the diaphragm. Tilt the navigator beams, so that the signal intensity of the kidneys is not affected (compare Fig. 2).

The navigator has a new off-center readout support. If you shift the center of the navigator to the dome of the diaphragm, the respiratory trace, generated by the interface between the lung and liver, will be shown in the middle of the Inline Display. A scout mode is therefore no longer necessary. Due to the automatic tracing, the system will

detect the end expiration phase automatically. This new capability to off-center the navigator in the Z direction is essential for applications where the anatomy of interest is significantly offset from the diaphragm in the Z direction. Make sure that the coils for the kidneys, as well as for the navigator in z-axis direction, are selected.

The next step is to position the imaging FOV. Set the upper border of the FOV very close to the origin of the vessel of interest. Do not include too much proximal aorta in the FOV. To maximize the inflow effect, the upper limit of the inversion band should exactly match the upper limit of the FOV. This way, there will be no loss of signal of the inflowing, arterial blood. For the inversion pulse, a new graphical element has been designed and a new parameter subcard implemented into the UI (Fig. 3). The graphical element of the inversion pulse covers a larger area inferiorly, to also saturate the inflowing blood from the veins and therefore, prevent the veins from causing unwanted signal in the images.

Finally, set the captured cycle. The maximization of the inversion time is automated within the sequence and there is usually no need to change this parameter. To verify this value, it can be checked on the Geometry-Inversion subcard.

The acquisition time is usually between 2–5 minutes, strongly depending on the heart rate and the breathing cycle of the patient. Monitor the navigator signal and the ECG- triggering during the measurement, to ensure a successful completion.

**4** Example of a *syngo* NATIVE TrueFISP MIP reconstruction (healthy volunteer).

Postprocessing

Coronal and axial Maximum Intensity Projections (MIPs) are reconstructed Inline. For reconstruction of radial ranges, load the 3D dataset to the 3D-card and use the MIP and radial ranges button.

For further evaluation, the ThinMIP button can also be used and the volume adapted to the maximum possible. Figure 4 shows a radial ThinMIP reconstruction of a healthy volunteer.

Challenges and possibilities

- Imaging of renal transplants: In the pelvis region motion artifacts due to breathing are not usually of great significance. Thus, the respiratory gating is not needed in this region. There is a dedicated protocol for this specific application in the Siemens Exam Explorer.
- In elderly patients or patients with a known heart failure, the stroke

volume may not be sufficient to fill the complete arterial tree of the kidneys with fresh blood within one heart cycle. In this case longer TI values such as 1400 ms may be useful. The UI allows 1400 ms when both acquisition window and TR are long enough. Keep in mind, that this leads to a situation where every second trigger signal is used, while the value of the trigger pulse parameter remains 1 (Fig. 5).
- Patient is dehydrated: Elderly patients in particular tend to drink less, which can have a negative influence on the blood volume and flow. Ensure that the patient is well-prepared for the examination. Perhaps communicate that topic with the responsible medical doctor.
- ECG-signal is disturbed during the measurement. Try to position the ECG amplifier in the direction of the head rather than the feet.
- In some cases, the detection of the renal arteries may be difficult on the
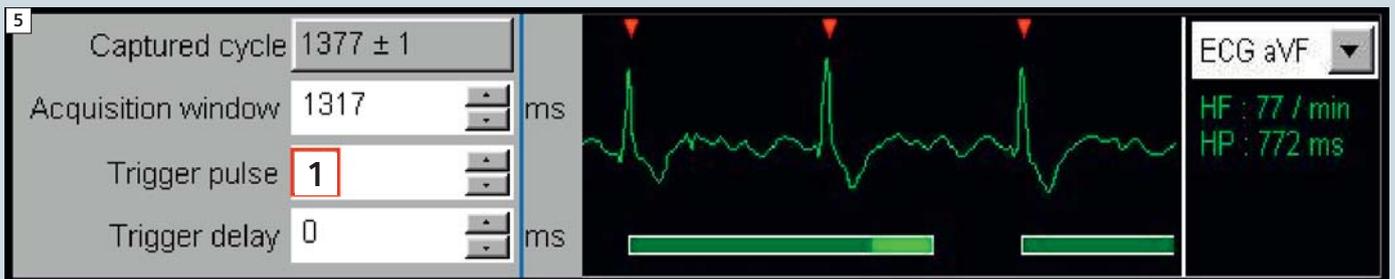
5 Trigger settings for long TI values (every second trigger used).

TrueFISP Localizer. Alternatively, an axial and coronal multi-breath-hold HASTE sequence can be run.

The theory behind *syngo* NATIVE SPACE

The *syngo* NATIVE SPACE sequence is a flow-sensitive 3D Turbo Spin Echo (TSE) sequence which allows fast scanning with high spatial resolution.
The sequence offers non-selective refocusing pulses and thus ultra-short echo-spacing.
The contrast of the *syngo* NATIVE SPACE sequence is based on the difference in the signal-intensity between static or slow-flowing blood (diastole) and fast-flowing blood (systole).
In diastole, the arteries appear bright (bright blood image). In systole, the arteries are dark (black blood image). *syngo* NATIVE SPACE includes two measurements in one protocol, each with a different trigger delay. One measurement is acquired when the blood within the vessel is at its peak velocity, the other at its lowest velocity. The two images are subtracted voxel-wise, which removes background and venous signals, and the user is presented with immediate results (Inline subtraction and Inline coronal MIP). The Inline functionalities are chosen on the subcard Inline-Common. To manipulate the sensitivity to moving spins, different flow spoiling gradients can be selected.
The key to obtaining best image quality is to clearly identify the flow patterns in the R-R cycle. For this purpose, a cine FLASH sequence with a fairly high flip angle is used. The high flip angle enhances the in-flow effect.
Another important point is a stable ECG-signal, since the data must be collected consistently at the right time in the cardiac cycle. Therefore, ensure the correct positioning and preparation of the ECG device.

Patient preparation

The patient is positioned feet-first supine. The protocol in the Siemens Exam Explorer is set up with the peripheral angiography coil and the upper spine coil elements. Position the laser marker on the centre of the lower leg.

Protocol set-up

The standard exam consists of three protocols:
- a TrueFISP localizer including imaging of coronal and transversal slices
- a Cine_TDscout, and
- the NATIVE_SPACE_3D sequence.

The localizer starts automatically. Position the FOV of the Cine_TDscout sequence transversely in the middle of the scan range. Use the captured cycle button to set the number of phases. Load the images of the Cine_TDscout to the Mean Curve Application and draw a circle over an artery in each leg and begin the evaluation.
The scale on the curve image can be changed to Trigger Time, using the right mouse-button and selecting Scaling/Sorting.
Figure 6 shows a typical result of a healthy volunteer. In this case, you can easily identify the peak flow and the slow flow period.
The Cine_TDscout may also be used as a predictor for the chance of success. If the selected vessel does not show pulsatility in the flow pattern, it is very likely that the NATIVE SPACE technique will not provide enough contrast.
When running a multi-step protocol, it is beneficial to perform as many cine scouts as imaging steps. The trigger delay for each step may vary significantly (normally around 20–30 ms for each step). If a peripheral angiography with multiple steps is preferred, use the Tim Planning Suite and add as many steps as necessary. Figure 7 shows the
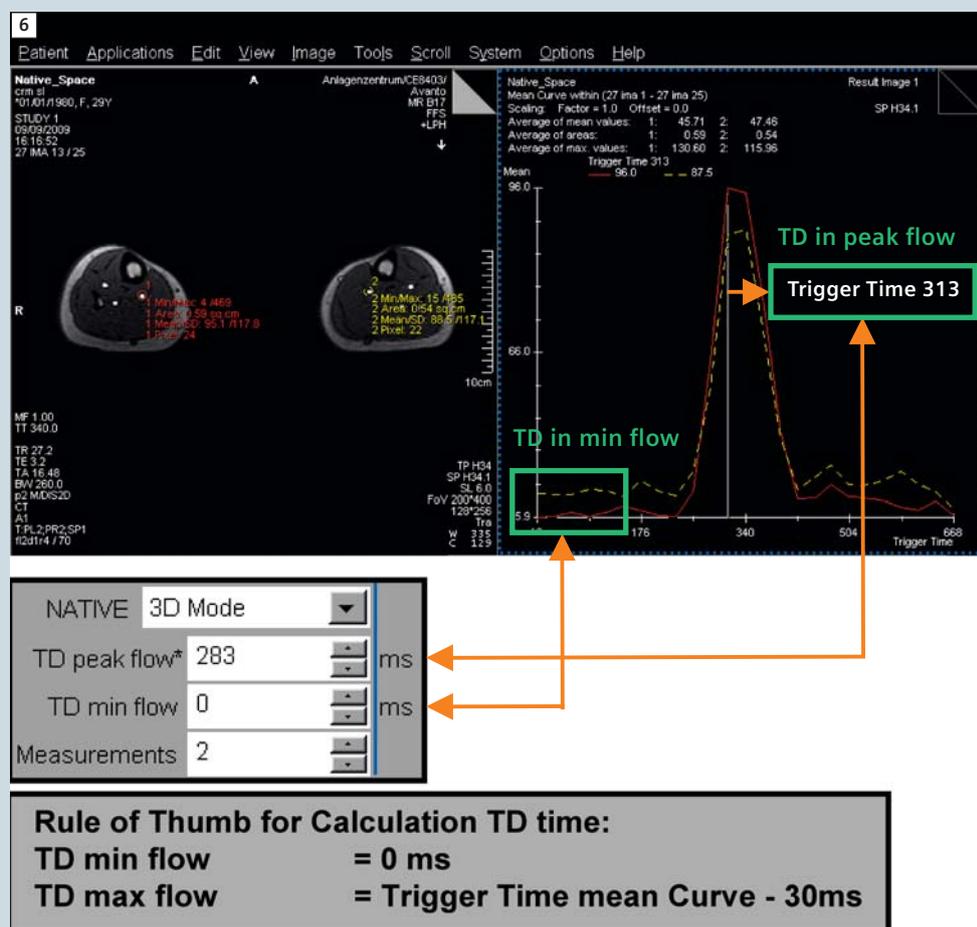
6 Mean Curve Application within the *syngo* NATIVE SPACE protocol and calculation of the delay times.
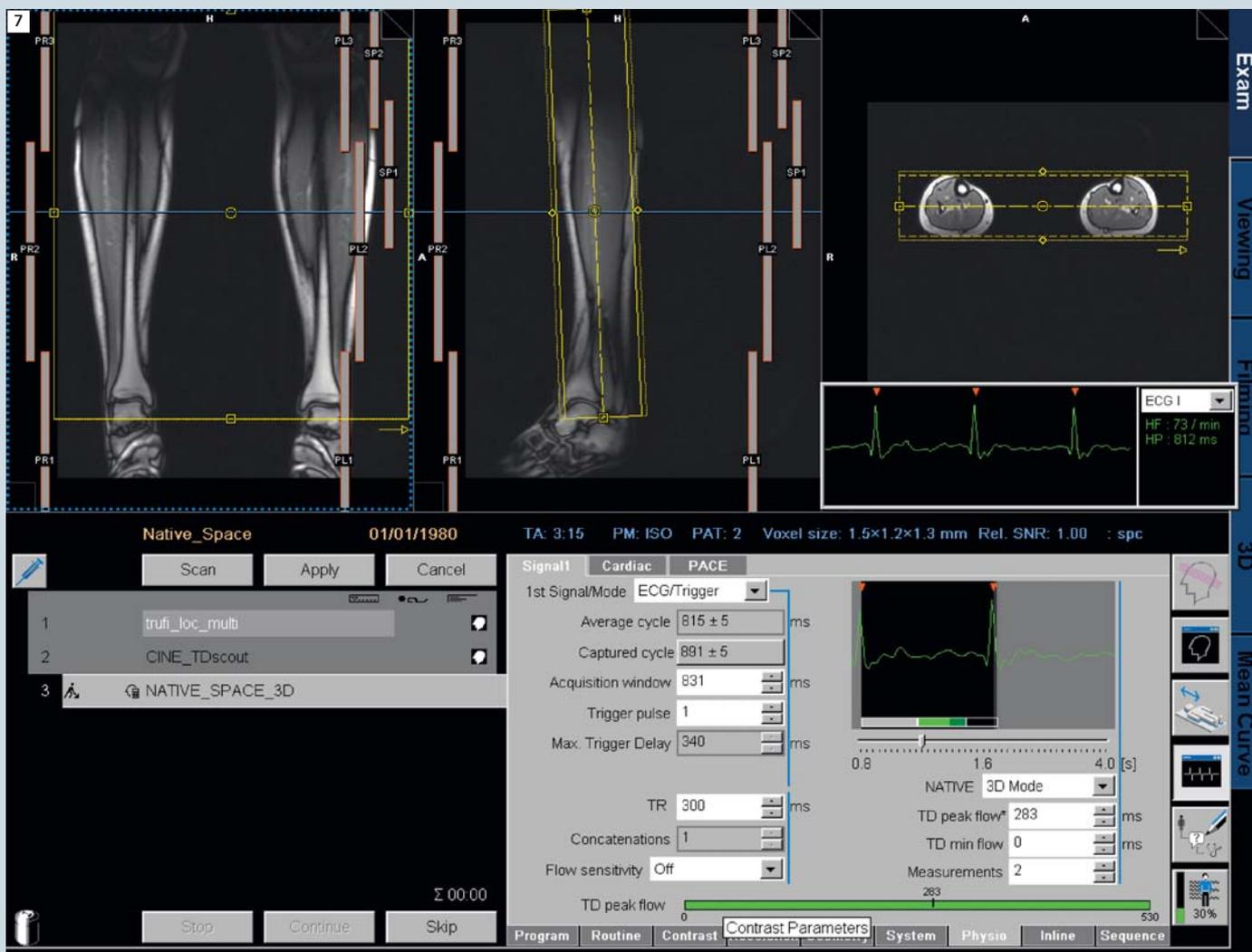
7 Planning of a single-step standard protocol in the lower leg region.

planning of a single-step standard protocol in the lower leg region.

Do not forget to adapt the time delay for the peak flow to the corresponding area. To set the Trigger Delay times for the peak and the minimum flow, open the 3D SPACE sequence on the Physio – Signal 1 subcard. We have good results by subtracting 30 ms from the peak trigger time in the Mean Curve Application, as shown in Fig. 6. In most cases, a trigger delay of 0 ms should be well-suited for the minimum flow acquisition. During the scan remember to monitor the stability of the ECG.

As a result of the *syngo* NATIVE SPACE sequence, four different image series are displayed in the Viewing Card:

■ Peak Flow image with dark arteries
■ Min Flow image with bright arteries
■ Inline subtraction showing arteries only, and
■ Inline coronal MIP (Fig. 8).

Postprocessing

Similar to the *syngo* NATIVE TrueFISP sequence, an Inline coronal MIP is reconstructed to give a first impression. For further manipulation, load the subtracted data to the 3D card. Comparable to the *syngo* NATIVE TrueFISP postprocessing, also try the ThinMip button for refinements. Figure 9 shows a multi-step MIP approach on a healthy volunteer.

Challenges and Possibilities

■ The method can be considered as robust even if contrast agent has already been applied. Therefore, the technique may be used as a backup, if a contrast-enhanced examination did not work out perfectly.
■ If there are different blood transit times on each leg due to a severe stenosis in one extremity (seen on the Cine_TDscout images in the Mean Curve application card), consider running two measurements, each of them optimized for one leg.
■ Reduced contrast behind stenosis due to lack of pulsatility of flow and high-grade change of direction: To enhance the flow sensitivity, work with the

8 Results derived from a *syngo* NATIVE SPACE non-ce MR angiography exam.
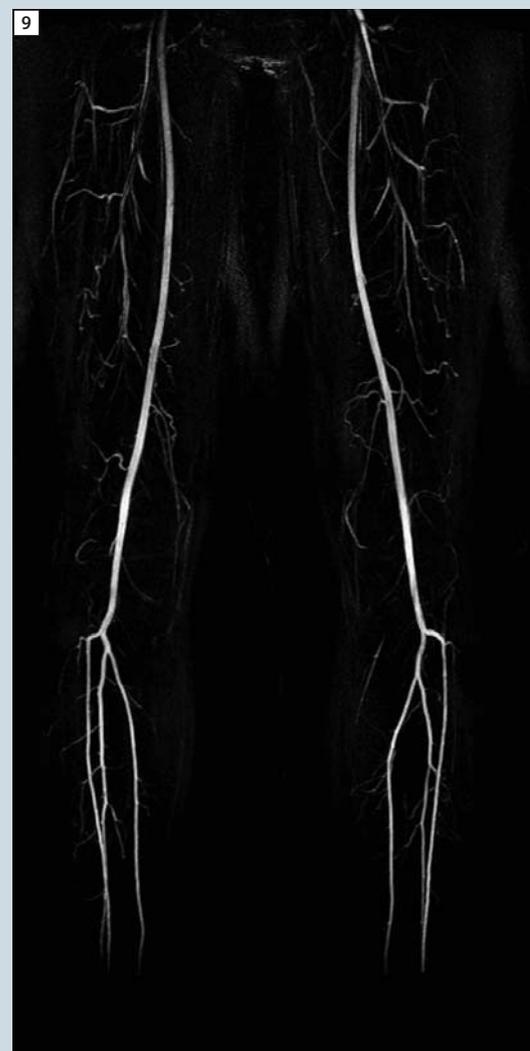
9 Coronal MIP of a multistep protocol.

extra flow sensitizing spoiler gradients. They support the collection of dark blood images since they additionally destroy the signal in moving blood. There are four different possibilities available (found on Physio-Signal1 subcard):

- **off** – means the normal way of using the flow-spoiling gradients as implemented in the *syngo* SPACE sequence. (Value between weak and medium.)
- **weak** – no flow-spoiling gradient used (Value = 0%)
- **medium** – higher flow sensitivity than "off", due to sophisticated spoiler gradients (Value = 25%)
- **strong** – highest flow sensitivity (Value = 50%)

Conclusion

syngo NATIVE SPACE and *syngo* NATIVE TrueFISP do not claim to replace contrast-enhanced angiography, but are complementary methods in cases where contrast agent is not applied for different reasons or where the contrast technique did not turn out well.

With these techniques, the user can overcome known weaknesses of the non-contrast enhanced MR angiographies used to date and may improve the overall diagnostic value of the MRI examination.

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