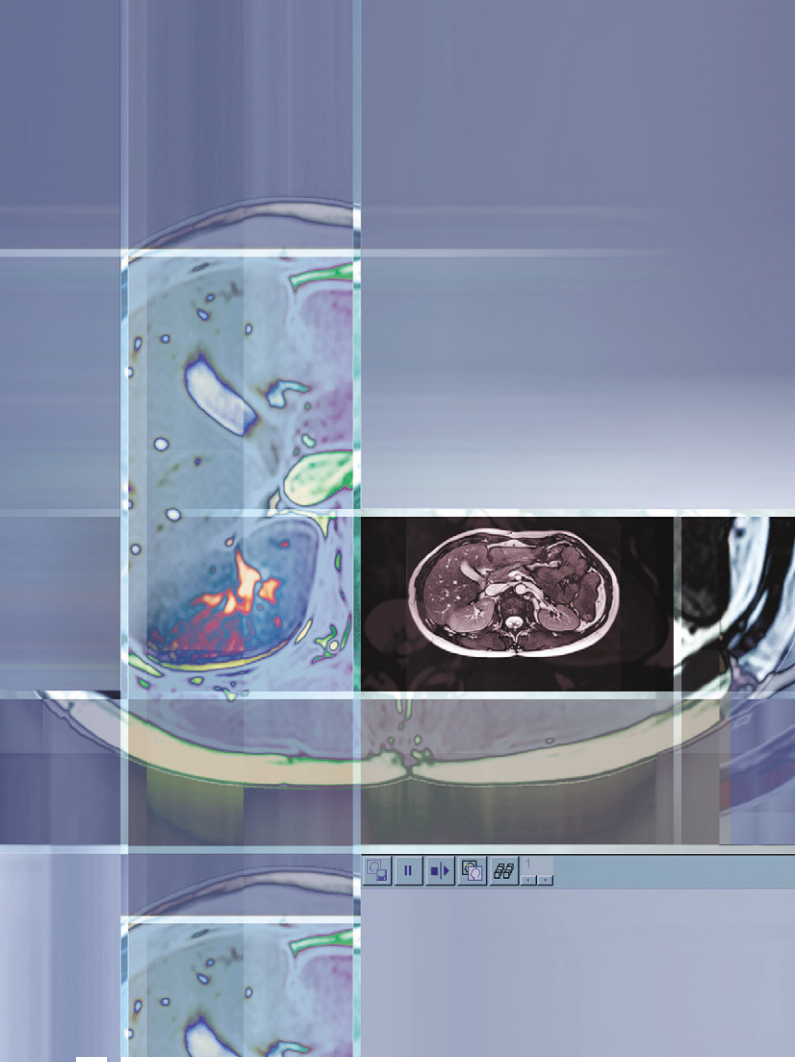

Body Imaging

Application Brochure

MAGNETOM Avanto
MAGNETOM Symphony a Tim System
MAGNETOM Trio a Tim System
MAGNETOM Verio

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Body Imaging

Application Brochure

MAGNETOM Avanto
MAGNETOM Symphony a Tim System
MAGNETOM Trio a Tim System
MAGNETOM Verio

This brochure provides you with information about body imaging with *syngo* MR.
It has been developed for medical personnel in the area of MR tomography.

To optimize the readability of this brochure, its contents have been divided into two subject matters.
The first part of the brochure provides basic knowledge of the topic. The second part is based on practical application and describes several applications using the most important elements of an examination.

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Body imaging

This brochure addresses the application of whole-body imaging as well as local applications, with a focus on the abdomen.

Abdominal MR imaging

Abdominal imaging displays organs of the epigastric region. Most radiological examinations in the area of abdominal diagnostics deal with serious pathological issues. For this reason, quality requirements are exceptionally high.

Application

- Evaluation of epigastric organs, vessels and ducts
- preoperative diagnostics
- follow-up examinations

Advantages

- non-invasive
- freely-selectable slice orientation
- radiation-free exposures
- high spatial and temporal resolution

Whole-body imaging

A considerable number of pathologies are of systemic nature and require a large measurement field. This volume is often larger than the homogeneous region of the scanner. The Tim concept optimally supports this requirement. Multistep measurements with automatic table movement followed by subsequent image composition are simplified by the Tim Planning suite. *syngo* TimCT—imaging with continuous table move—enables easy measurement preparations and homogeneous image quality across larger measurement ranges.

Whole-body imaging is not necessarily examining from "head to toe", but tailors its overall measurement field to the existing or suspected disease.

This brochure describes in particular the imaging of tumors and inflammations. Separate information is available for the field of angiography.

Requirements to be met by abdominal imaging (I)

Radiological requirements on the one hand, and anatomical or physiological requirements on the other, present certain challenges in the area of abdominal imaging.

We will be using the liver as an example. For one of the largest organs of the body, the number and position of even the smallest lesions have to be known for subsequent therapy. This requires:

- good contrast
- high resolution
- no artifacts
- complete coverage of large body regions

The organs of the abdomen are affected by a number of motions that make it difficult to obtain images free of artifacts such as:

- respiratory motion
- peristalsis
- pulsation of different arteries, especially the aorta

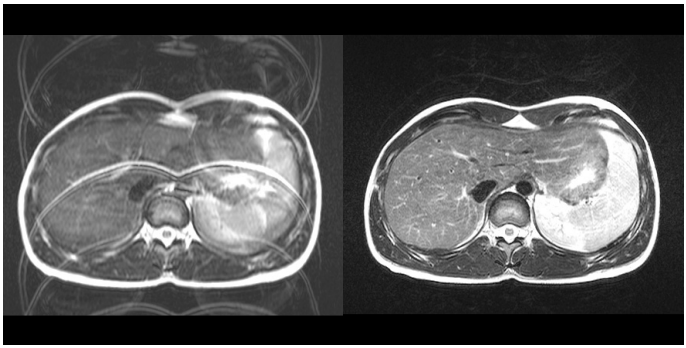


Image with (left) and without respiratory artifacts (right)

Requirements to be met by abdominal imaging (II)

Abdominal imaging requires high-performance gradients and array coil systems in addition to fast sequences and measurement techniques for reducing respiratory artifacts.

Sequences

Fast or ultra-fast sequences are used for abdominal imaging.

- Single-shot sequences (e.g., TurboFLASH, HASTE)
- Multi-shot sequences for 2-D and 3-D measurements (e.g., TSE, GRE)
- VIBE for 3-D measurements



FLASH with fat saturation (left) and HASTE (right)

Measurement techniques

Techniques for reducing respiratory artifacts include measurements during one or several respiratory breathholds as well as measurements with gating during normal breathing. In detail these are:

- Single/multi-breathhold techniques (without 2-D PACE) > p. 8
- Multi-breathhold techniques (with 2-D PACE) > p. 10
- Measurement with respiratory gating during normal breathing > p. 16
- Measurement with navigator gating during normal breathing > p. 20

Single/multi-breathhold technique

Single breathholds

If the patient can hold his breath sufficiently long, the entire measurement can be completed in a single breathhold. In this way respiratory artifacts are largely avoided. However, this requires excellent cooperation on the patient's part, since he has to hold this breath for about 20 s.

Multi-breathholds

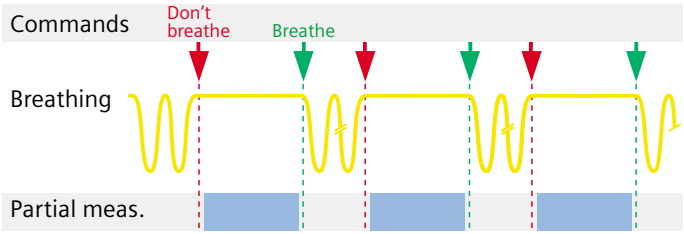
However, in reality several breathhold intervals are usually required to fully cover the anatomy of interest. The number of breathhold intervals depends on the number of concatenations.

Concatenation

Concatenations subdivide the overall measurement into partial measurements. The number of concatenations corresponds to the number of partial measurements.

Example: The measurement time is 36 seconds, however, the patient can hold his breath for 15 seconds only. For this reason, the measurement is split into three partial concatenated measurements of 12 seconds each. The length of the pauses between the partial measurements is freely selectable.

Please note: In the multi-slice mode, **single measurements** combined with the **Long term** averaging mode, the number of breathhold intervals also depends on the number of averages.



Dividing a measurement into three concatenated partial measurements

To minimize shifts within a measurement slice, all partial measurements have to be acquired during the end inspiration or end expiration phase.

Multi-breathhold techniques: with 2-D PACE (I)

For measurements with multi-breathhold technique, the patient is not consistently breathing in or out the same way. The slice blocks of the partial measurements are offset to one another.

PACE

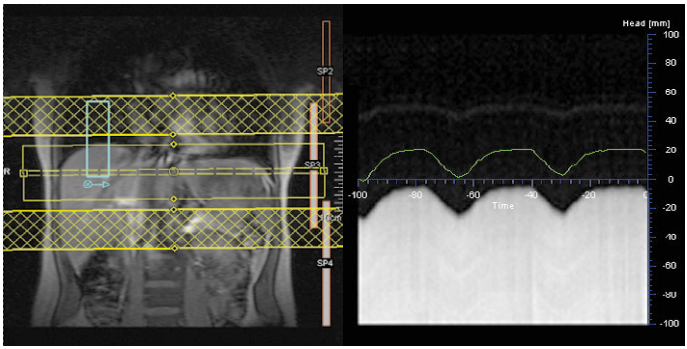
With multi-breathhold protocols, the shift between the slices measured during the different breathhold intervals can be reduced by using a navigator for detecting respiratory motion (PACE = Prospective Acquisition CorrEction).
The navigator technique used with abdominal imaging is known as *2-D PACE*.

Please note: However, this method cannot prevent artifacts resulting from a less than perfect breathhold.

Navigator

The navigator of the abdominal 2-D PACE module is a low-resolution gradient echo image in the phase-encoding direction. The flip angle of the navigator stimulation is so low (between 3° and 6°, depending on the sequence), that the diagnostic images seem to be free of saturation stripes caused by the navigator.

Under certain circumstances, especially when water collects in tissue (e.g., ascites), the navigator may cause a saturation stripe. This stripe cannot be misinterpreted.



Navigator (left, turquoise rectangle) and display of respiratory motion (right, without measurement interruption)

Multi-breathhold techniques: with 2-D PACE (II)

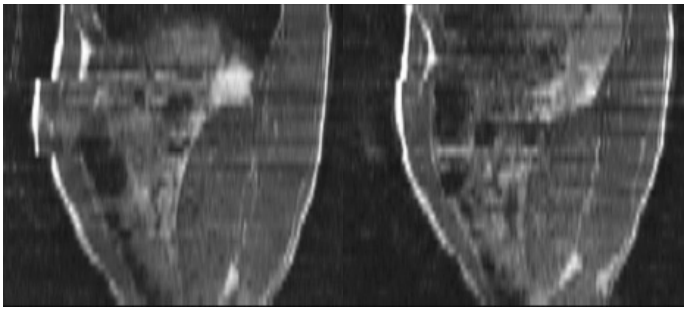
Slice correction

The navigator helps determine the different inspiration/expiration levels via the diaphragm position. The resulting slice shift will be reduced in the measurements to follow.

Comparative block method

The navigator image taken prior to the *first* partial measurement is stored as a reference image. Prior to measuring *additional* partial measurements, the image blocks in the navigator images are compared to the image blocks in the reference image. When the image blocks have been shifted, the shift necessary for the slice to be measured is derived by comparing positions.

Tracking factor If the shift is not larger than the full height of the acceptance window, the slice is shifted by the tracking factor during data acquisition. In case of larger shifts, the slice is not shifted by the tracking factor.



Sagittal MPR of transverse liver images, without (left) and with shifting the slice by the tracking factor (right)

Since respiratory motion is three-dimensional within the abdomen, it cannot be fully compensated by shifting the slice by the tracking factor. For this reason, the width of the acceptance window should remain within a reasonable size.

Normal breathing and gating

Breathhold techniques are difficult or impossible to apply with uncooperative patients. As a result, measurements have to be performed during normal breathing. Additionally, measurements during normal breathing may be more comfortable for cooperative patients as well.

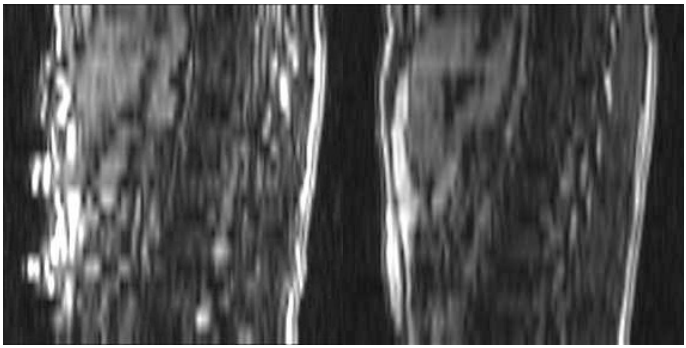
Continuous data acquisition with normal breathing leads to image artifacts with multi-shot sequences (e.g., TSE). For single-shot sequences (e.g., HASTE), these artifacts can be avoided when acquisition is short compared to the breathing cycle. However, with multi-slice measurements, the individual slices are acquired during different respiratory phases. The positions of the epigastric organs vary depending on the respiratory phase. The anatomical order of the slices no longer corresponds to the order of the slice positions.

Gating

To avoid this, gated measurements are being used. Gating is the reference point in the physiological signal that triggers data acquisition. It synchronizes respiratory motion and data acquisition.

Depending on how the respiratory information of the patient is being measured, two different methods are available.

- Respiratory gating: The respiratory signal is acquired with a respiratory cushion.
- Navigator gating: Respiratory motion is monitored via the navigator.



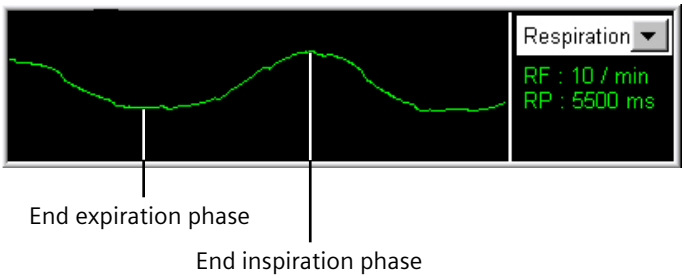
MPR of a series comprising 20 transverse slices, acquired without (left) and with gating (right)

Measurement during normal breathing: with respiratory gating (I)

Respiratory gating is used to keep artifacts caused by respiratory motion to a minimum.

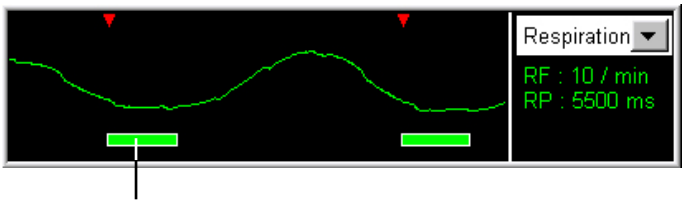
Respiratory cushion

Respiratory motion is transferred to a respiratory cushion. The cyclic expansion or contraction of the thorax is displayed as a respiratory curve in the **Physio Display**. The respiratory signal rises during inspiration and falls off during expiration. It is used to generate the gating signal as a function of the respiratory phase selected.



Acquisition window

When using a respiratory cushion, selection of the acquisition window is of great importance.
To minimize motion artifacts, the acquisition window is typically selected during expiration. A partial measurement is started as soon as the respiratory signal falls below the threshold set. Its maximum duration is set by the length of the acquisition window.
When the respiratory curve falls again below the trigger threshold, the next partial measurement is started, etc. until all data have been fully acquired.



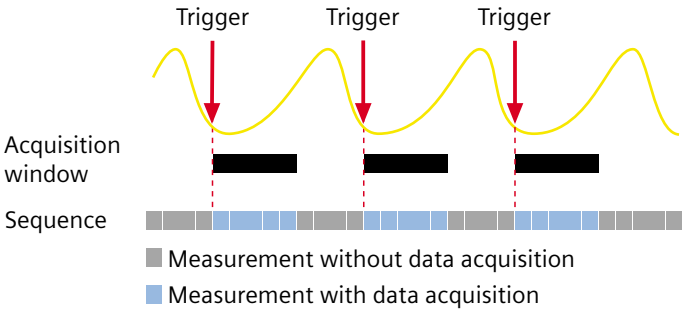
Acquisition window

Measurement during normal breathing: with respiratory gating (II)

Since the average respiratory period is typically between 4 – 6 seconds, measurement pauses of several seconds occur during which the system waits for the next respiratory period. While these measurement pauses facilitate acquisition of T2-weighted images, T1 weighting is difficult to obtain due to the relaxation of the magnetization.

T1 weighting with gre

The gradient echo sequence *gre* is suitable for this particular application. To ensure T1 weighting despite respiratory gating, the measurements between the two acquisition windows are continued, however, without data acquisition. The basic principle behind it is shown in the following figure.



The number of measurements with data acquisition corresponds to the number of segments on the Physio task card

Measurement during normal breathing: Navigator gating with 2-D PACE (I)

During navigator gating, a navigator is used for monitoring respiratory motion.

Sequences

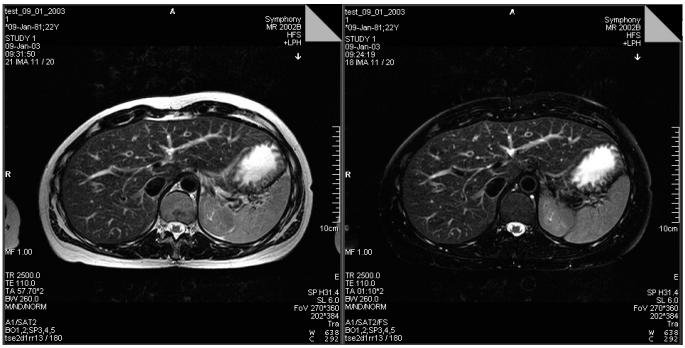
Navigator gating is available for the following sequences:

- T2 weighting: TSE, TSE with Restore, HASTE
- T1 weighting: TurboFLASH
- TrueFISP

Application

- Multi-shot sequences for uncooperative patients
- Single-shot techniques: For acquiring temporal series and comparing result images (e.g., subtraction)
- For cooperative patients in place of multi-breathhold techniques (increased patient comfort, better T2 contrast (long effective TR) and/or better resolution)
- Acquisition of high-resolution 3-D cholangiograms

Disadvantages As compared to respiratory gating with an external device (e.g., respiratory cushion), no respiratory signal is available while preparing for the examination or acquiring anatomical data.



T2-weighted liver images with navigator-gated TSE sequence, without (left) and with fat suppression (right)

Measurement during normal breathing: Navigator gating with 2-D PACE (II)

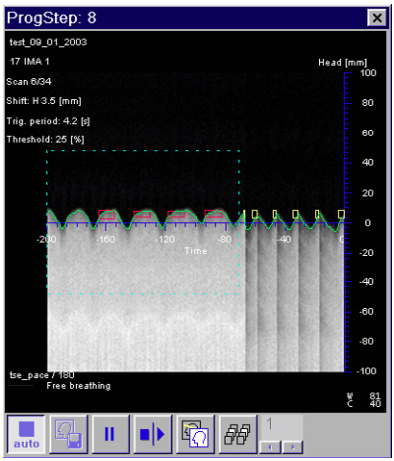
The navigator-gated measurement can be divided into two phases: the learning phase and the imaging phase.

Learning phase

During the learning phase, the "respiratory pattern" of the patient is learned to establish the center position of the acceptance window during the imaging phase. During the first five respiratory cycles, the navigator acquires the respiratory cycle without interrupting the measurement. During this period, respiratory motion is continuously shown in the Inline Display. Beginning with the second respiratory cycle, a red rectangle shows the period proposed for data acquisition. The position of the red rectangles is based on the parameters set and on the evaluation of preceding respiratory cycles.

Width/height of the red rectangle

The width of the red rectangle corresponds to the acquisition duration. Height and vertical position of the red rectangles are set so that they fully cover the motions of the diaphragm during the proposed period. The parameters are set correctly when the data are acquired toward the end expiration.



Navigator-gated respiratory curve. The turquoise window (position of the navigator) marks the learning phase.

Measurement during normal breathing: Navigator gating with 2-D PACE (III)

Reducing the acquisition window

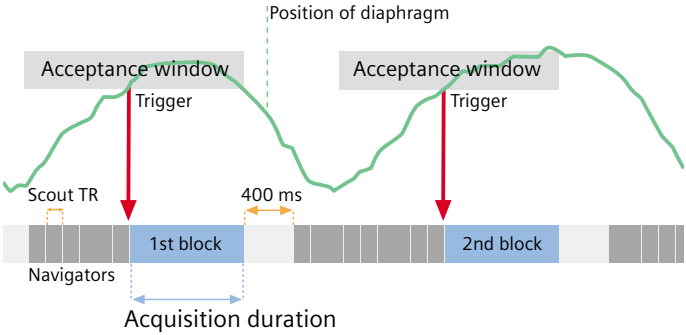
If the width of the red rectangles is larger than 1/2 of the breathing period (horizontal distance from maximum inspiration to maximum inspiration), the measurement has to be terminated and the acquisition duration reduced. In this manner, artifacts can be avoided. The acquisition duration can be reduced as follows:

- TSE sequences: smaller Turbo factor or fewer slices per concatenation
- Single-shot HASTE sequences: lower basic/phase resolution or reduced FoV in the phase-encoding direction
- both types of sequences: wider bandwidth per pixel

Imaging phase

At the beginning of the imaging phase, the navigator is repeated at constant time intervals (Scout TR) in order to acquire the positions of the diaphragm. As soon as the detected diaphragm position falls within the acceptance window, the navigator is no longer repeated and the first block of the actual imaging sequence is started. The measurement time for one block corresponds to the acquisition duration.

- Contiguous TSE sequences:
  n echo trains are acquired per block;
  one echo train per slice of the current concatenation
- Single-shot HASTE sequences: one complete slice is measured per block



Imaging phase of navigator-gated sequence. 400 ms after completing one block, the navigator is repeated until the next suitable respiratory phase is located. There is no gating during inspiration (acceptance window is interrupted).

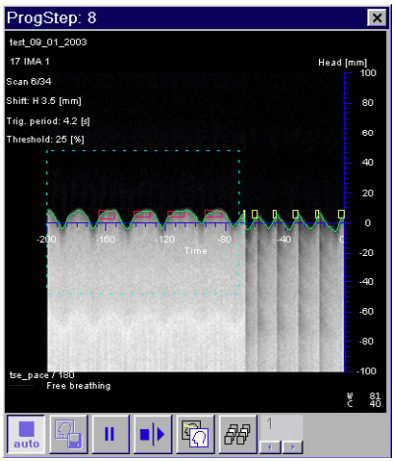
Measurement during normal breathing: Navigator gating with 2-D PACE (IV)

Gating conditions

Gating is performed when the last diaphragm position detected lies within the acceptance window.

Respiratory curve

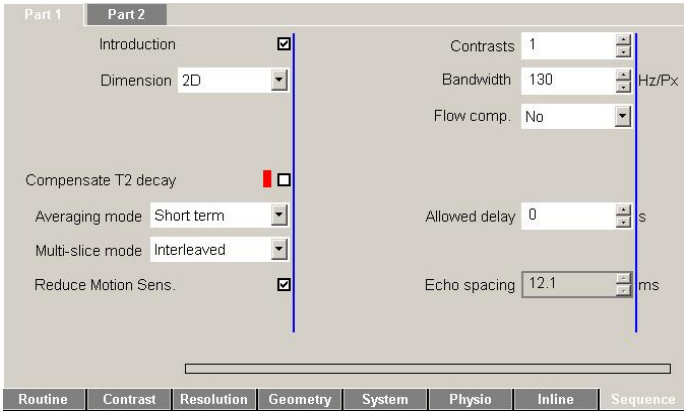
In the imaging phase, the respiratory curve is no longer displayed during data acquisition. As soon as expiration begins, the acceptance window is shown as a yellow rectangle. The height of the acceptance window corresponds to the value of the **Acceptance Window ±** parameter on the **Physio PACE** parameter card. The center of the acceptance window is either determined by the system during the learning phase or is set manually. As soon as the detected diaphragm position (green curve) falls into the acceptance window, the first block of the imaging sequence is started.



Navigator-gated respiratory curve

Reduced motion sensitivity

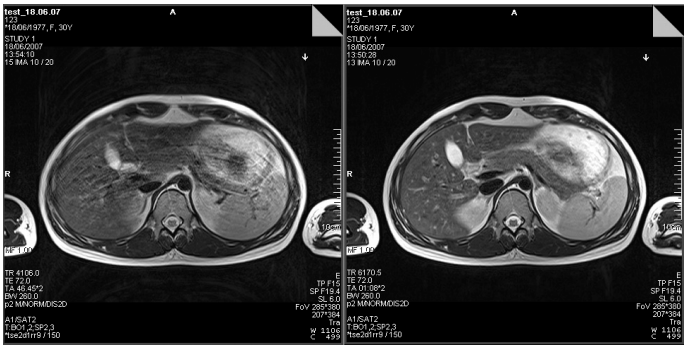
For small patient movements, motion artifacts are reduced significantly by enabling the **Reduce Motion Sens.** checkbox on the **Sequence/Part 1** parameter card of the TSE sequence.



Applications

- T2-weighted measurements of head, spine, pelvis, and hip
- T2-weighted abdominal applications based on TSE with PACE free breathing

Please note. The technique is less effective for application setups with higher Turbo factors. For this reason, breathhold measurements of lung and abdomen are *not* recommended.



TSE images without (left) and with reduced motion sensitivity (right)

For the TSE sequence, the BLADE technique may also be used to reduce motion sensitivity. Detailed information about BLADE is available in the *application brochure Pulse Sequences*.

MR colonography

MR colonography avoids the disadvantages and concomitant poor acceptance of conventional coloscopy.

MR colonography is a minimally invasive method for imaging polyps or tumors of the colon as well as inflammatory intestinal diseases.

Advantages

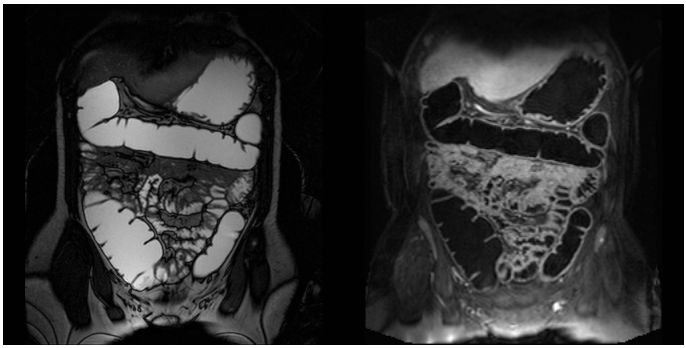
- minimally invasive
- without the risk of intestinal perforation
- all areas of the intestines can be viewed
- evaluation of the large intestine when endoscopic evaluation is impossible due to tumor growth
- it is also possible to examine organs outside the colon

Intestinal wall contrast—inside the intestines

To clearly delineate polyps, sufficient contrast between the intestinal wall and the inside of the intestines is required. To this end, the intestines are filled with water. This will also cause the intestinal walls to expand.

Depending on the signal intensity of the interior of the intestines as compared to the intestinal wall, two different acquisition methods may be selected.

- Bright lumen colonography
- Dark lumen colonography



Bright lumen image (left) and dark lumen image (right)*

** not available for 3 T systems*

Bright lumen colonography*

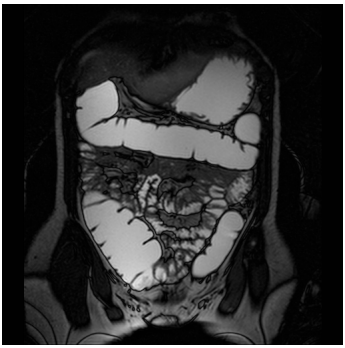
When compared to the intestinal wall, bright lumen colonography shows a hyperintense signal in the interior region of the intestines. To increase contrast, a contrast agent can be added to the water. It is *not* necessary to use an intravenous contrast agent.

Characteristics Acquiring 2-D or 3-D data sets.

Advantages 2-D sequences are not as sensitive to motion artifacts.

Disadvantages Residual air in the intestinal lumen appears dark in the image. Only part of the intestinal sections involved can be evaluated since polyps may hide in air-filled spaces or, conversely, air bubbles may be incorrectly interpreted as polyps. This requires imaging the patient in the prone as well as supine position.

** not available for 3 T systems*



Bright lumen image

Dark lumen colonography

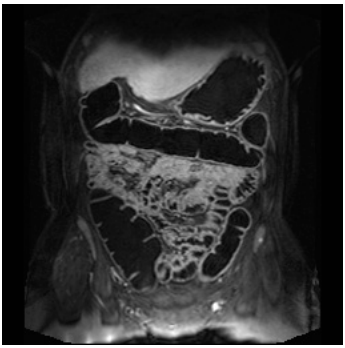
The problems experienced in differentiating polyps/air bubbles when using bright lumen imaging led to the development of dark lumen colonography.

With dark lumen colonography, the interior of the intestines is shown as hypointense as compared to the intestinal wall. Intravenous contrast agent is added for increasing contrast.

Characteristics Acquiring 3-D data sets

Advantages

- Polyps are shown as bright, while the intestinal lumen and air bubbles are shown as dark. This facilitates image evaluation.
- In general, polyps enhance contrast agents more quickly than colonic tissue. When comparing images before and after contrast agent enhancement, polyps are determined more easily.
- Also, the use of contrast agent facilitates detecting pathologies outside the colon (e.g., liver lesions).



Dark lumen image

Measuring dynamic signal changes in the abdomen (I)

2-D and 3-D protocols are available for measuring dynamic changes in signal in different organs and tissues.

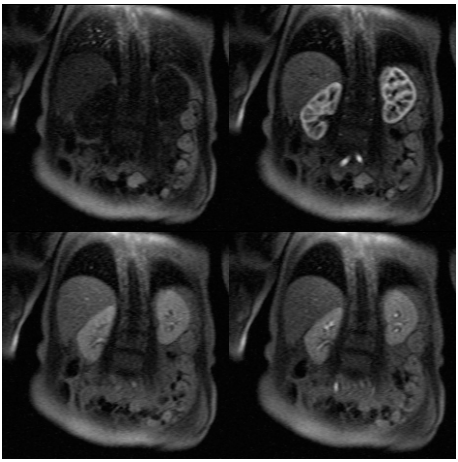
Temporal resolution/ planning

Fast temporal changes in signal intensity require the highest possible temporal resolution for the measurement. To realize very short temporal intervals between measurements, the number of slices possible as well as their spatial resolution is limited. This is why slice planning plays an important role so as to acquire the organs that are of interest.
The multi-slice TrueFISP localizer in the protocol tree is suitable for displaying the kidneys and the renal artery.
When selecting and adjusting a protocol, it is important to take into account the temporal resolution for the changes in signal to be monitored.

2-D measurements

During 2-D measurements, a low measurement time is selected for individual slices so that a respiratory shift in the organ seems to be frozen during image acquisition time and is of negligible importance. The measurement protocols consist of a sequence of slices that are acquired in the single-shot technique, one after the other. The orientation of the individual slices may be different. The temporal resolution is determined by the number of slices.
The organ is motion-corrected during image post-processing.

Example: Measurement of dynamic signal changes with SR-FLASH



Measuring dynamic signal changes in the abdomen (II)

3-D measurements

Using the same parameters, 3-D measurements show a better SNR than 2-D techniques. However, by necessity their measurement time is longer.
This is why motions and their effects play a role during the measurement. It is important to either avoid or, if present, correct respiratory motion.
The breathhold technique is a simple and effective method for reducing spatial shifts in organs and for performing measurements of high temporal and/or spatial resolution.
In case of temporal changes considered slow in relationship to the measurement time, the signal course can be documented by using repeated measurements at suitable intervals.

Base line

The base line plays an important role when evaluating the time course of the signal. The base line is determined by the constant signal value of a tissue prior to observing temporal signal changes.
Several sequence techniques require a number of excitation cycles until a steady state is reached.
It is recommended to perform a measurement that allows for easy definition of the base line without adversely affecting the monitoring of fast signal changes. For this reason, separate measurements are performed including only a few repeats prior to dynamic changes.

Measuring dynamic signal changes in the abdomen (III)

Magnetization has to be prepared to measure dynamic signal changes.

None-selective saturation

When using saturation pulses, the protocol name includes _sr_. Non-selective saturation is characterized by generating a uniform magnetic state with vanishing longitudinal magnetization for all tissues. Once in this state, the sequence-specific signal is generated as a function of the tissue-specific relaxation times.

Saturation with an IR pulse

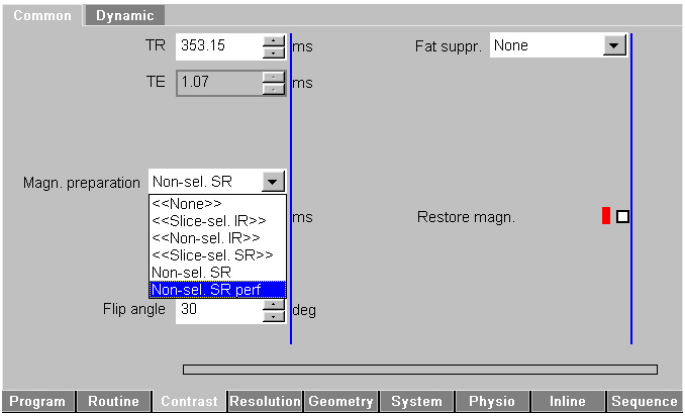
Magnetization prepared by an inversion pulse with suitable inversion time is often used for displaying differences in signal. What needs to be considered in this case is the occurrence of signal fluctuations in case of long relaxation times. In case of signal changes with short T1 relaxation, ambiguous signal contributions may occur. For this reason, examinations with time-dynamic imaging are run *without* using a protocol with inversion pulse.

Slice-selective saturation

During slice-selective preparation, the signal is also affected by the blood flowing into the slice. These types of effects should be avoided for signal analyses that are largely based on changes in relaxation time.

Selection of saturation pulse

For a comparison of the signal time curves of different tissues it is required to assess a complete and homogeneous saturation over the complete selected imaging volume. In order to achieve this, an optimized saturation pulse should be used which can be accessed via the **Contrast-Common** parameter card.



Measuring dynamic signal changes in the abdomen (IV)

Aliasing artifacts

Examinations with time-dynamic imaging of the kidneys are usually performed in the coronal orientation. The phase-encoding direction runs in this case from left to right. With small field of views (FoV), aliasing artifacts may occur caused by the arms aligned along the sides of the patient. These artifacts are acceptable only if they do not adversely affect the signal for the kidneys.
Otherwise, the FoV has to be enlarged or phase-oversampling has to be used.

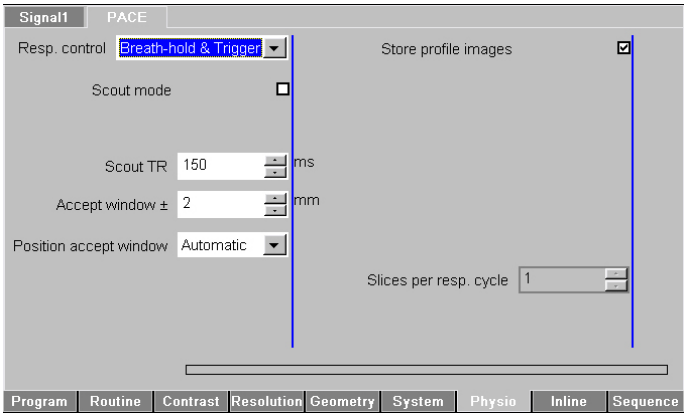
Evaluation software

Either MeanCurve or Argus DSA may be used for displaying signal-time curves. Both programs are suitable for drawing tissue regions and performing base line corrections. The contour can be automatically synchronized during regional evaluations with Argus DSA.
(Refer to "Tissue 4D" in the *syngo* MR Operator Manual.)

Time-dynamic imaging with 2-D PACE (I)

Usually, the early phase of the measurement should be performed with high temporal resolution. During this time interval, a breathhold acquisition is performed. The images that follow can be measured, however, at a larger time interval due to navigator gating.

Both phases of this type of measurement follow one another automatically. The number of breathhold measurements as well as the number of slices per respiratory cycle are shown on the **Physio PACE** parameter card.



Learning phase

The learning phase is at the beginning of the time-dynamic image acquisition with combined breathhold measurements and gating. The parameters determined during this phase are used for subsequent measurements with gating.

Imaging phase

After the learning phase, a respiratory command is issued and the requested number of images is required without interruption. Following this procedure, the automatic navigator-gated measurement begins up to the end of the repetitions set.

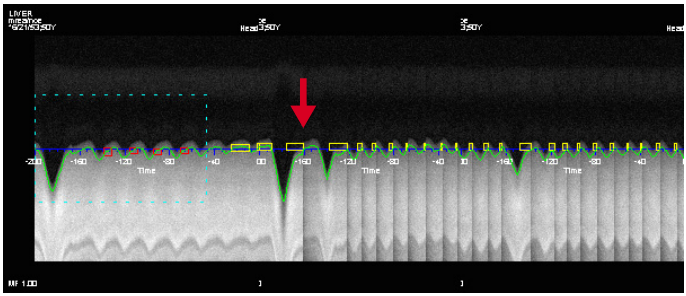
Please note: It is important that the position of the diaphragm during the breathhold closely corresponds to the learned breathing position for gating.

Advantages

By combining the two methods of fast data acquisition and gating, signal evaluation across a longer acquisition time was improved. Whenever possible, organs and vessels are acquired during the same respiratory position and partial volume effects vertical to the slice plane due to motion are reduced. Currently, these methods are implemented in the *tfl* sequence.

Time-dynamic imaging with 2-D PACE (II)

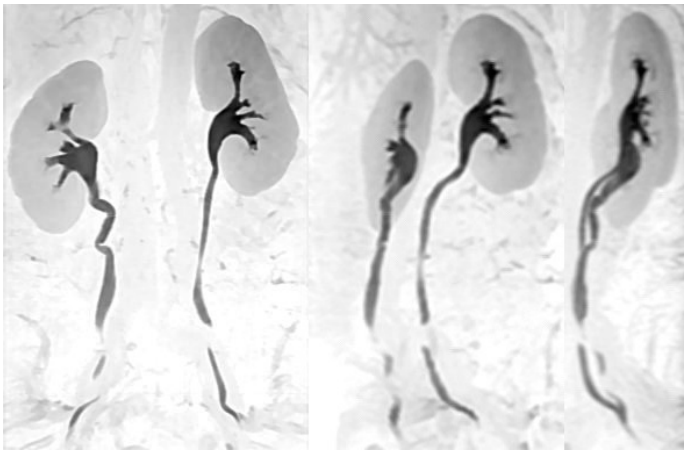
The following figure shows the course over time for a time-dynamic image acquisition using navigator signals.



After the learning phase, a deep respiratory intake period is visible. A temporal high-resolution measurement is acquired via the following met gating conditions (red arrow). The navigator signals are not displayed to the end of the breathhold measurements. However, all following acquisitions are measured with respiratory gating.

Urographic display (I)

Using dynamic procedures, it is possible to display renal calyces, the renal pelvis and the urinary tract collection system with a 3-D sequence.



Different projection angles of a MIP reconstruction during a dynamic measurement (inverted display)

You can either compute a maximum intensity projection (MIP) or a multiplanar reconstruction (MPR).

Due to their peristaltic movement and anatomical position, it is frequently impossible to fully display ureters. However, it is also possible to repeat the measurement several times to acquire peristaltic waves. Additionally, it is helpful to provide patients with as much fluids as possible during urographic examinations.

Urographic display (II)

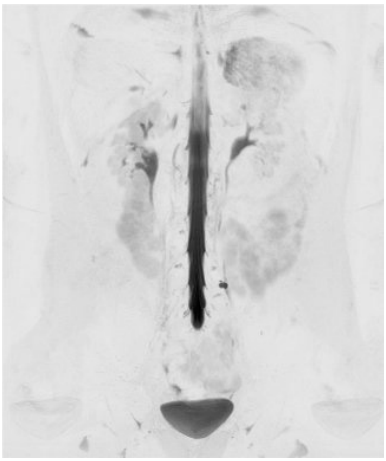
During a dynamic measurement the kidneys act to filter any substances out of the blood. This will result in an increased concentration of the substance within the kidneys. A corresponding extreme shortening of relaxation times is then likely.

MR urography at low concentration levels (inverted display)



As can be seen, it is possible to selectively display the renal calyces as well as the urinary tract collection system.

It is also possible to perform urography with strongly T2-weighted sequences. Strong hydrogenation of the patient is especially advantageous including compression of the lower abdomen, if required. The spinal canal is clearly displayed.



MIP reconstruction of a T2-weighted 3-D TSE image (inverted display)

REVEAL: Body imaging with diffusion weighting (I)

Diffusion-weighted imaging shows an increased potential for differential diagnosis in evaluating body lesions. It proved to be superior to other techniques in differentiating malignant (e.g. hepatocellular carcinoma, metastasis) versus benign lesions (e.g. cysts, hemangiomas, focal nodular hyperplasia). Accurate lesion detection is necessary for subsequent therapy planning or follow-up of lesions.

Technique

MRI shows the diffusion effect using a proper pulse sequence which acquires diffusion-weighted images (images in which areas of rapid proton diffusion can be distinguished from areas with slow diffusion).
Therefore the pulse sequence applies to a so-called diffusion gradient. The diffusion of water molecules along this field gradient reduces the MR signal depending on the diffusion ability of the water protons. In areas of lower diffusion, the signal loss is less intense and these areas are displayed brighter.

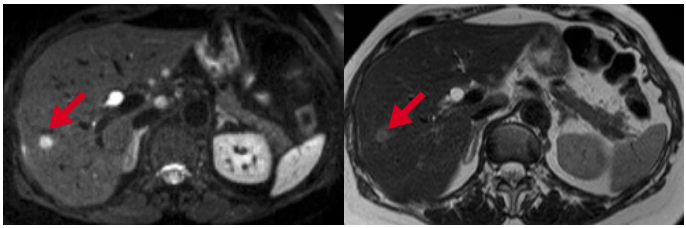
For body diffusion, trace-weighted single-shot EPI sequence techniques are used (ep2d_diff, see Application Brochure "Pulse Sequences"), which apply diffusion gradients of specific strength and direction. The strength of the diffusion gradients is determined by the b-value [s/mm^2]. Typically, an iPAT factor of 2 (GRAPPA) is used to shorten the echo train and reduce sensitivity to susceptibility. For a good fat suppression, which is essential for single-shot EPI applications, a fat saturation pulse is applied or STIR in difficult regions with artifacts caused by unsaturated fat (e.g. for breast diffusion with REVEAL).
Finally, images are generated which clearly show the diffusion status within the anatomy.
Additionally, apparent diffusion coefficient maps (ADC maps) can be generated which provide the best in-vivo pseudo-quantification of diffusion effects. Normally malignant lesions show lower ADC values than benign lesions due to restricted water molecule motion in the presence of a tumor.

REVEAL: Body imaging with diffusion weighting (II)

Two approaches for body diffusion with REVEAL are available.

Low b-value imaging

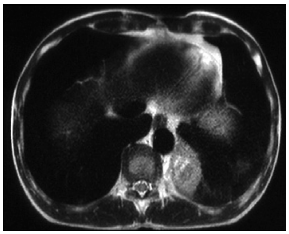
Low b-value ($b \leq 50$ s/mm^2) application of REVEAL to obtain high lesion conspicuity with dark vessels. No differentiation between benign and malignant lesions is possible. Image acquisition can be performed within one breathhold or with a freely breathing patient to increase SNR. This technique is beneficial for, e.g. liver examinations as a fast acquisition add-on to the standard program.



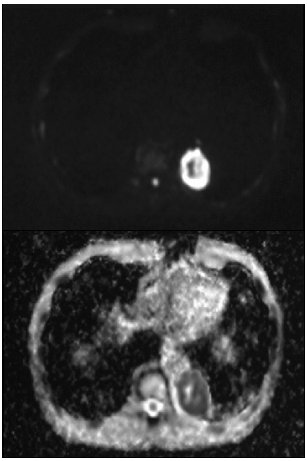
Dark vessel liver imaging with single-shot EPI diffusion sequence with fat saturation, b-value = 50 s/mm^2, in one breathhold (left) compared to T2-weighted breathhold Turbo spin echo with fat saturation (right). Improved visibility of lesions as compared to the standard T2-weighted liver imaging with Turbo spin echo sequence normally showing bright vessels.

High b-value imaging

Diffusion-weighted imaging with three b-values in the range from 50 – 1000 s/mm^2.
With a b-value above 800 s/mm^2, a very good suppression of normal tissue is obtained and essentially tissue with a high cellularity (characteristic for malignant lesions) shows up. Image acquisition can be performed within one breathhold or in free breathing to increase SNR.



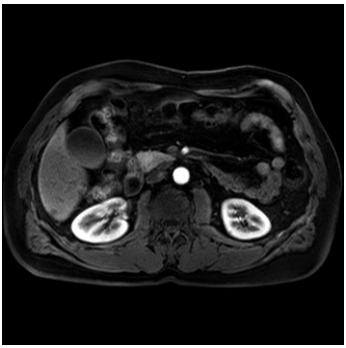
T2-weighted image



Potential of lesion differentiation with high b-value imaging: the malignant lesion shows up bright in the high b-value (b-value = 1.000 s/mm^2) diffusion-weighted image (upper right). Due to restricted diffusion, the tumor has a low ADC (lower right).

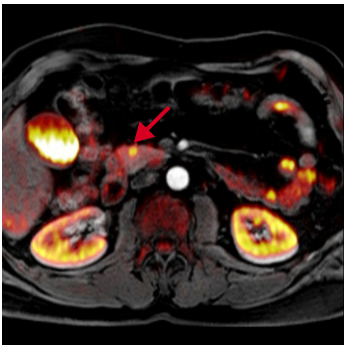
REVEAL: Body imaging with diffusion weighting—Fusion

The **Fusion** function of the **3D** task card* provides increased clinical benefits when a high b-value, diffusion-weighted data set, which highlights mainly malignancies, is combined with anatomical data. This allows for a more precise localization of pathologies in relation to the surrounding tissues.



VIBE post-contrast,
PAT 2 with GRAPPA in 22 s,
eff. 3 mm slice, 448 matrix

** refer to the syngo Operator Manual*



Fusion of diffusion-weighted (EPI with FatSat, b 500) and anatomical data set. Insulinoma in the pancreas head (see arrow), Courtesy of St. Augustinus, Wilrijk, Belgium

Fat suppression: Overview

Due to the different chemical environment, water- and fat-bound protons have different values for some MRI-relevant parameters, mainly being the relaxation time and the resonance frequency (chemical shift). These differences can be used to selectively suppress/reduce the signal of fat protons. Thus relaxation-dependant and chemical shift-dependant methods can be used for fat suppression.

Recommended fat/water selective techniques

	STIR	SPAIR		FatSat		Water ex.	Dixon
		Standard	Mode weak/strong	Standard	Mode weak/strong		
TSE/SE	✓	✓	✓	✓	✓	–	–
HASTE	✓	✓	✓	✓	✓	–	–
SPACE	✓	✓	✓	✓	✓	–	–
FLASH-2D	–	–	–	✓[b]	✓[c]	–	–
VIBE	–	✓[a]	–	✓[d]	–	✓	✓
REVEAL	✓	✓	–	✓	–	✓	–
TFL	–	–	–	–	–	✓	–
TrueFISP	–	–	–	✓	–	✓	–

[a] "Lines per shot" can be selected
[b] both FatSat and Quick FatSat available
[c] only with Quick FatSat available
[d] with Quick FatSat "Lines per shot" can be selected

Comparison of different fat suppression techniques

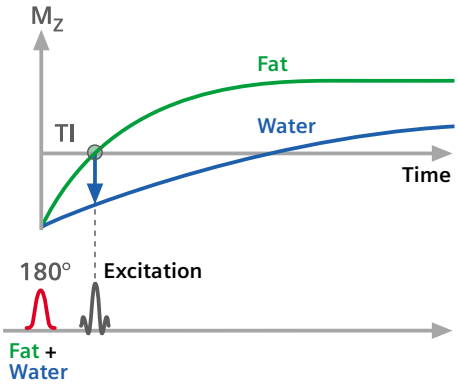
Technique	Advantages	Disadvantages
STIR > p. 60	• Insensitive to B_0 inhomogeneities	• Timing changes TR, TA • Contrast affected
SPAIR > p. 62	• Insensitive to B_1 inhomogeneities • High performance (quick mode) • Contrast not affected	• Timing changes TR, TA
FatSat > p. 64	• High performance (quick mode) • Contrast not affected	• Sensitive to B_0 and B_1 inhomogeneities • Timing changes TR, TA
Water excitation > p. 66	• Insensitive to B_1 inhomogeneities • Contrast not affected	• Timing changes TE, TR
Dixon > p. 68	• Insensitive to B_0 and B_1 inhomogeneities • Multiple contrasts generated • Contrast not affected	• Timing changes TR

Fat suppression: Inversion Recovery (STIR)

The STIR technique (Short TI Inversion Recovery) is based on the different relaxation behavior of water and fat tissue.

Principle

Fat has a much shorter T1 relaxation time than other tissues. Prior to the excitation pulse of the sequence, a 180 degree inversion pulse is applied which inverts the spins of all tissues. The tissues perform T1 relaxation. By choosing TI so, that the longitudinal magnetization of fat is zero at that time, fat spins will not contribute to the MR signal.
STIR images have an inverted T1 contrast: tissue with long T1 appears brighter than tissue with short T1.



Advantages

- Insensitive to B_0 inhomogeneities

Disadvantages

- Additional inversion pulse increases minimum TR and total measurement time or reduces maximum number of slices
- Tissue contrast is affected

Applications

- Detection of metastasis in the abdominal region

STIR PACE free breathing



Fat suppression: SPAIR

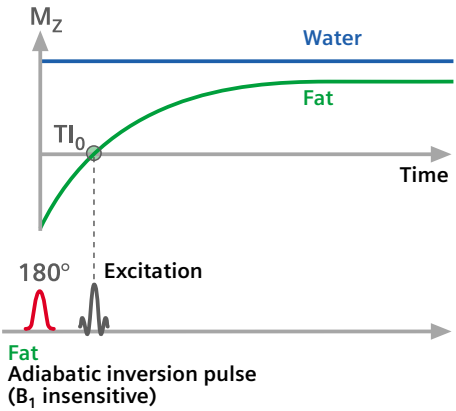
The SPAIR technique (Spectrally Adiabatic Inversion Recovery) is an alternative to the conventional "spectral fat saturation" or "water excitation" methods.

Principle

A spectrally selective adiabatic inversion pulse excites only fat spins, thus no STIR-like contrast is created. With gradient spoiling the transverse magnetization is destroyed.
The inversion time TI_0 is such that the longitudinal magnetization of fat is zero at that time. As a result fat spins will not contribute to the MR signal.

SPAIR Mode

Two modes (strong/weak) are available for SE-type sequences.



Advantages

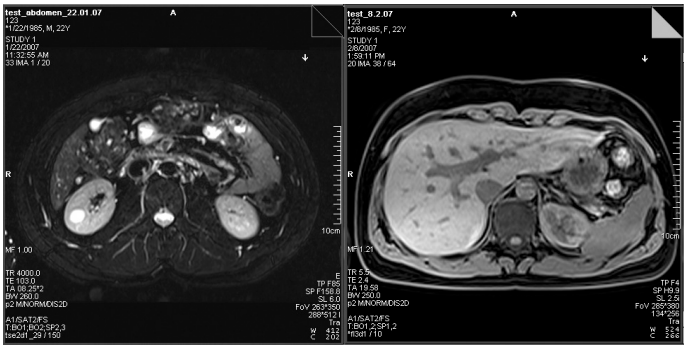
- Insensitive to B_1 inhomogeneities
- Tissue contrast is not affected
- Quick FatSat can be applied for increased performance (VIBE)

Disadvantages

- Increased minimum TR or reduced maximum number of slices due to more complex preparation pulse (partially compensated by Quick FatSat)
- Slightly reduces overall signal intensity in single-shot sequences (Reveal)

Applications

- Abdominal breathhold applications with TSE, SPACE, HASTE, and VIBE
- Fast T1-weighted breathhold applications based on VIBE (with proper setting of the parameter “Lines per shot”)



T2-weighted TSE SPAIR multi-breathhold (left),
T1-weighted VIBE SPAIR breathhold (right)

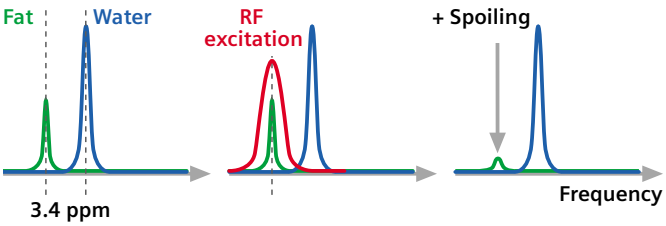
Fat suppression : Spectral fat saturation

Spectral fat saturation is based on the chemical shift (3.4 ppm) i.e., the difference in resonance frequencies between fat and water protons.

Principle Applying a narrow band frequency-selective RF pulse, mainly fat protons are excited. This transverse magnetization is destroyed afterwards by spoiler gradients, leaving no fat magnetization for imaging.

Quick FatSat With Quick FatSat, not every slice excitation is preceded by a preparation pulse. Thus shorter TRs can be set, and therefore breathhold examinations are possible (e.g., VIBE, recommended 40 lines/shot).

FatSat Mode Two modes (strong/weak) are available.



Advantages

- Tissue contrast is not affected
- Quick FatSat can be applied for increased performance

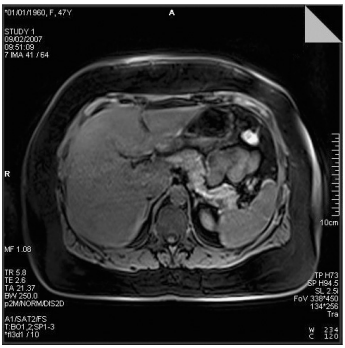
Disadvantages

- Sensitive to B_0 and B_1 inhomogeneities
- Additional preparation pulse increases minimum TR and total measurement time or reduces maximum number of slices (partially compensated by Quick FatSat)

Applications

- T2-weighted abdominal applications with fat saturation based on TSE, SPACE, and HASTE
- Fast T1-weighted breathhold applications with Quick FatSat based on FLASH-2D, and VIBE

T1-weighted VIBE with Quick FatSat

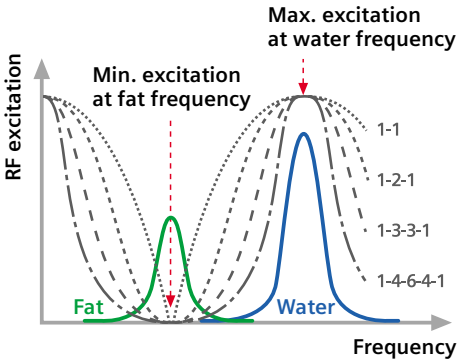


Fat suppression : Water excitation

Water excitation is base d on the chemical shift, i.e., the difference in resonance frequencies between fat and water protons.

Principle

No additional preparation pulse is necessary, instead a special excitation pulse (binomial pulse) is used with the spectral excitation profile as shown below (minimum excitation of fat protons, maximum excitation of water protons).



Advantages

- Insensitive to B_1 inhomogeneities

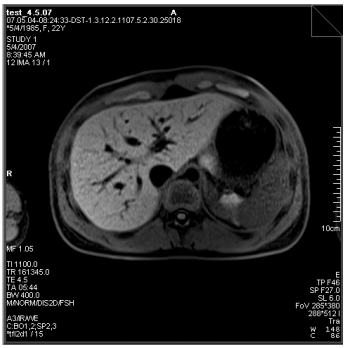
Disadvantages

- Increased minimum TE, TR and total measurement time or reduced maximum number of slices

Applications

- Frequently used on low field systems where spectral fat suppression is inapplicable
- Axial TurboFLASH applications with breathhold or PACE free breathing
- REVEAL applications in breathhold technique

T1-weighted TurboFLASH with water excitation and PACE free breathing



Fat suppression: Dixon technique

The Dixon technique is based on the chemical shift, i.e., the difference in resonance frequencies between fat and water protons.

Principle

With this technique two images are acquired. In the first image, the signals from fat and water protons are "in-phase", in the second they are in "opposed-phase". Via additional computations, separate fat and water images are calculated. The Dixon method is integrated into the VIBE sequence.

Advantages

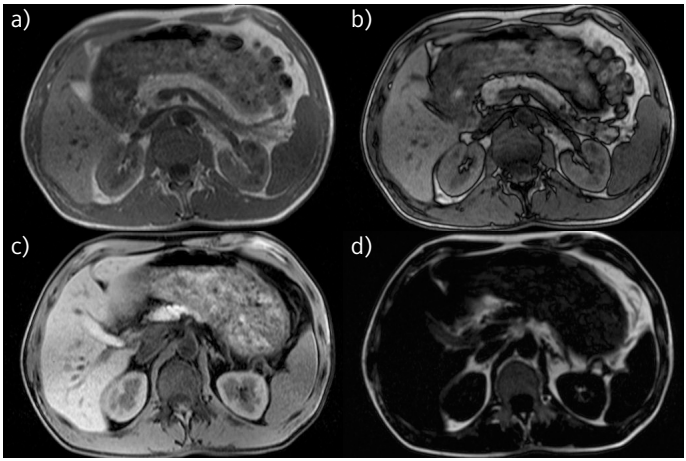
- Insensitive to B_0 and B_1 inhomogeneities
- Delivers up to four contrasts in one measurement (in-phase, opposed-phase, water, and fat image)

Disadvantages

- Increased minimum TR because in- and opposed-phase data must be acquired (partially compensated by using iPAT)

Applications

- Robust fat/water imaging in abdominal applications
- Fat quantification measurements



a) in-phase image
b) opposed-phase image
c) water image
d) fat image

Inline Liver registration

Multiple phases are acquired within a contrast-enhanced MR examination of the abdomen:

- native measurement (before administration of contrast media)
- arterial phase
- portal-venous phase and
- late phase

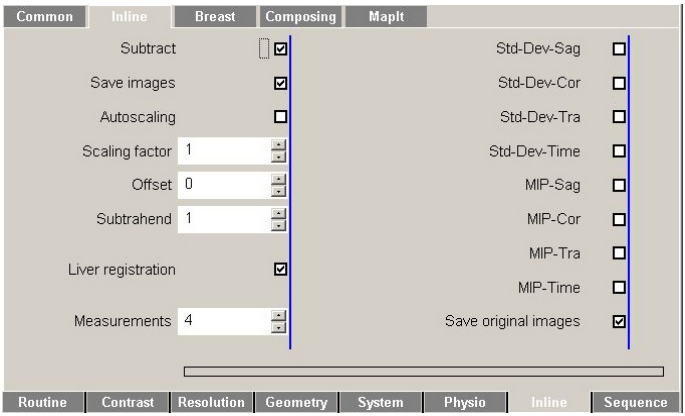
For diagnostic purposes, subtraction series are calculated by subtracting the native measurement from the arterial, portal-venous and late phase. When viewing original and subtraction images, *shifting* or *misalignment* of the anatomy may be observed between the different phases.

Cause

The same anatomical region is measured at different time points, each within one breathhold. Therefore, the anatomy under examination may shift substantially depending on the depth of the breathhold.

Remedy

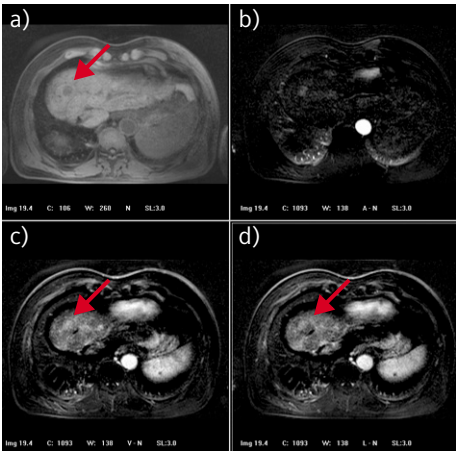
For best visualization of lesions regarding form, morphological information, or evaluation of the enhancement pattern, a mechanism of automatic registration/ alignment (= Liver registration) was implemented within the VIBE sequence.
Liver registration is performed when enabling the **Liver registration** checkbox on the **Inline** parameter card.



Inline Liver registration: Image examples

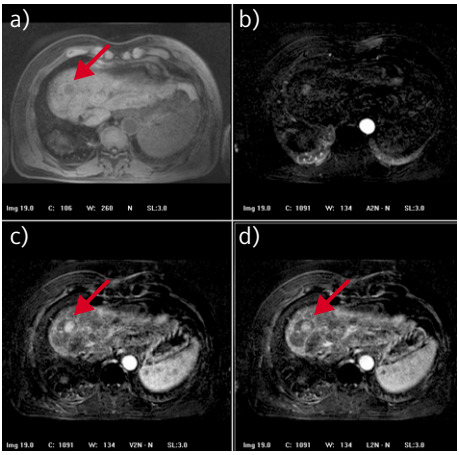
The importance of registration/correction can be seen when examining nodular enhancing pathologies. The improvement in subtraction quality between the registered and unregistered exam is self-evident in the images shown below.

Original images:
a) native
b) arterial phase
c) portal-venous phase
d) late phase
(b, c, d = subtraction images)



Patient with HCC, misalignement of the anatomy

Corrected images: a) native b) arterial phase c) portal-venous phase d) late phase (b, c, d = subtraction images)



Patient with HCC, better visualization of pathology after liver registration (see portal-venous and late phase)

MR thermometry: Applications/methods

MR thermometry based on temperature-sensitive sequences is used to display large temperature changes (≥ 15° C) in tissue.

Applications

- Radio-frequency ablation (RFA)
- Laser-induced thermotherapy (LITT, syn.: laser ablation)
- Tumor heating with focused ultrasound (FUS)

Restrictions

To adequately display temperature changes in organs, they have to be non-moving and show a low fat/water ratio.

- Typically suitable: head, uterus, prostate
- *Not* suitable, for example: breasts, liver, kidneys

Methods

Several methods are available for displaying temperature changes via MRT. These are differentiated depending on the type of temperature-sensitive MR parameters:

- T1 or T2
- Diffusion coefficient
- Proton resonance frequency (PRF)

Software version *syngo* MR B17 implements the PRF method only.

PRF method

The PRF method is based on the temperature-dependent precession frequency of water protons. A gradient-echo sequence is used for visualizing the temperature distribution. The phase of the transverse magnetization is determined *before* (reference images) and *during* hyperthermia (TMap images).
The PRF method does not provide absolute temperatures; it is only suitable for measuring the distribution of time-dependent temperature changes.

MR thermometry: Safety aspects (I)

MR thermometry is a complex field which requires adherence to several important aspects.

Image distortion

Heavy image distortions may occur due to different artifacts which may lead to incorrect temperature displays. Corrective measures are *not* implemented in the software.

Voxel size

In poorly perfused issue, the difference in temperature between adjacent voxels or within a large voxel may be quite large (steep temperature gradients).
In this case only an average temperature is displayed for larger voxels. The maximum temperature of a very small area is not shown at all. As a result, the voxel size has to be adjusted to a specific application, for example, ≤ 1.5 mm for FUS ablation.

Temporal resolution

In case of very high heating or cooling rates, it has to be ensured that the measurement time per slice is not too long compared to the temperature changes of the entire examination.
Example:
At a heating rate of 20–30° C/10 seconds, an image has to be taken at least every 3 seconds.

MR thermometry: Safety aspects (II)

Fat saturation

Fat protons do not contribute to changing the MR signal. For this reason, it has to be ensured that the measurement is performed *with* a fat sat technique. Otherwise, the temperature displayed may have been incorrectly calculated. However, if thermometry is to be performed without fat saturation, a fat ratio has to be determined beforehand by using a suitable fat measurement technique. For values of ≥ 20%, the measurement should *not* be performed.

Water contents

Thermometry should not be performed for tissue with very low water contents (≤ 20%), for example, bones.

Signal-to-noise-ratio (SNR)

The signal-to-noise ratio has to be sufficiently high in the regions of interest. Otherwise, the temperature in the resulting TMap images may be assessed incorrectly.

Tumor diagnosis with whole-body imaging (TimCT Oncology)

The TimCT Oncology application package enables transverse 2-D multi-slice imaging with two different image contrasts (T1/T2) as well as continuous table movement.

Applications

- As an addition to high-resolution MRT for the primary diagnosis of tumors with the table in stationary position
- Metastases and lymph node evaluation in the thorax, abdomen, and pelvis

Advantages

- Full diagnostic information (primary tumor evaluation, localization of metastases and detailed anatomy) after just a *single* examination
- Coverage of large field-of-views (FoV)
- Highly homogenous image quality
- Fast and easy examination planning with TimCT

T1 contrast

The GRE sequence is available for T1 contrast; either with spectral fat saturation or as a double-echo sequence with DIXON reconstruction.

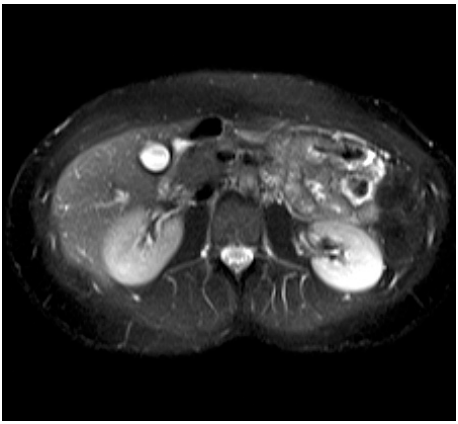
T2 contrast

The TSE or Haste sequences can be used for T2 contrast; either with spectral fat saturation or inversion recovery (STIR/TIRM). It is also possible to use the BLADE technique for TSE sequences.
For additional information regarding these sequences, please refer to the *Pulse Sequences Application Brochure*.

Sliding Multi Slice

Combining the sequences with continuous table movement requires an adapted slice and a k-space reordering scheme, known as Sliding Multi Slice.[1]

[1] Magnetic Resonance in Medicine 55:363-370 (2006)



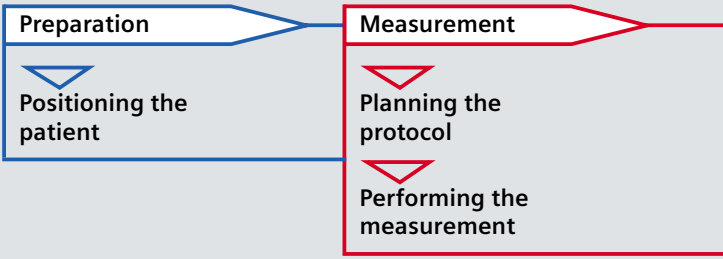
Acquiring abdominal images

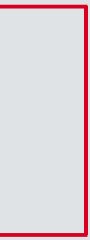
There are a number of different possibilities for performing measurements in the abdominal region. For this reason we are not showing a complete examination in what follows, but rather limit our description to the most important elements of it:

- Multi-breathhold measurement
- Multi-breathhold measurement with navigator
- Navigator-gated measurement
- Respiratory-gated measurement
- Dark lumen colonography
- Display of temperature changes
- Tumor identification with TimCT Oncology

Measuring multi-breathhold protocols

Using multi-breathhold protocols, you are able to plan all slices in a single examination protocol and manually start the slices of each breathhold interval.

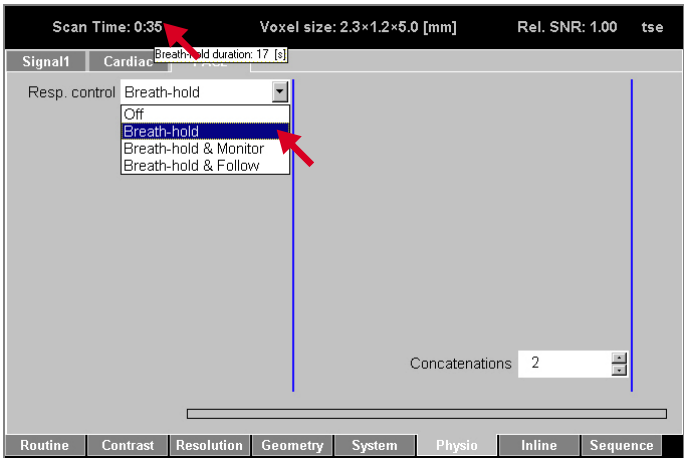




Planning a multi-breathhold protocol

Proceed as follows when planning a multi-breathhold protocol:

Select the breathhold option under the respiratory control parameter on the Physio PACE parameter card.



The duration of the breathhold is available as a tool tip of the measurement time.

Plan the slices as usual.
Select the number of concatenations to ensure comfortable breathholds for the patient. To this end, additional parameters relevant to the measurement time may have to be adjusted (e.g., TR, Turbo factor, phase resolution).

Measurement time
The *predicted measurement time* is computed from the measurement time of a breathhold interval (= duration of breathhold) and the number of breathhold intervals per measurement. The *actual measurement time* depends also on the length of the pauses between respiratory intervals and is not known beforehand.

Performing the measurement

Start the measurement of the protocol.

The option **Wait for user to start** (flagman) in the **Protocol step properties** dialog box is not required and should *not* be selected for multi-breathhold protocols.

Open the Inline Display.
Start the first breathhold command as soon as "Press Scan in Inline Display when patient holds breath" appears to the bottom left in the measurement time display.

Start the measurement after the patient is holding his breath.
For this purpose, click the "Scan Button" in the Inline Display.

The slices of the first breathhold interval are being measured.

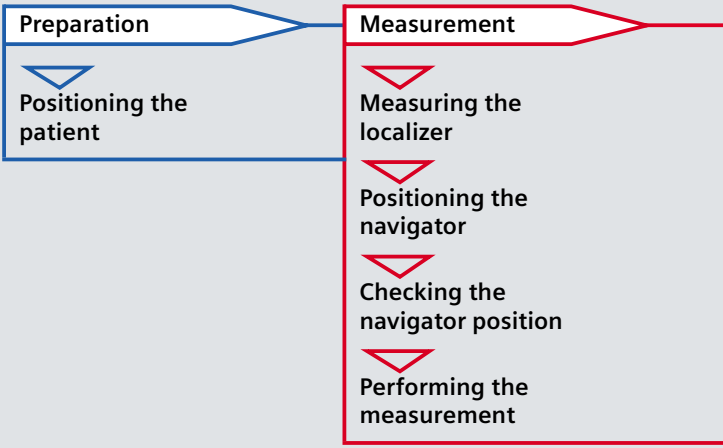
During the measurement, the time remaining for the breathhold interval is counted down in the measurement time display. Accordingly the number n in the measurement time display "Scanning breath hold... (1 of n)" stands for the number of breathhold intervals measured and *not* the number of individual measurements.

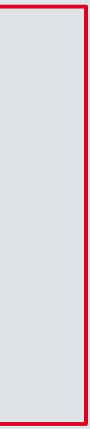
Repeat the last step for each breathhold interval.

Select the excitation sequence "Interleaved in breathhold".
In this way the shift between slices measured during different breathhold intervals can be minimized.

Measuring multi-breathholds with the navigator

The multi-breathhold technique is frequently used in practical application. We will present the technique in combination with the navigator for detecting respiratory motion.





Positioning the navigator (I)

Coronal and transverse localizers are available

When you select an option including navigator support under the **respiratory control** parameter on the **Physio PACE** parameter card, the system automatically adds a navigator to the examination protocol. Position the navigator in the localizer images.

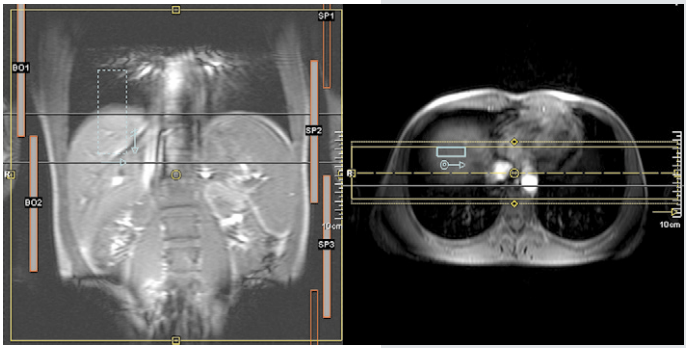
Change to the **Physio PACE** parameter card.

Select the Navigator with Slice Correction (Breathhold&Follow).

When you are using surface coils, pls. select a coil element in the vicinity of the navigator.

Change to the Geometry > Navigator parameter card.

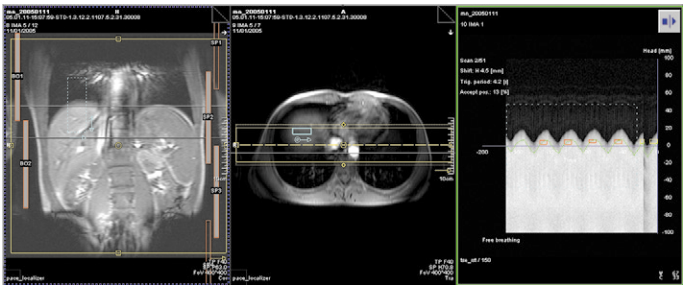
Select the navigator.
During graphic slice positioning the navigator is displayed as a turquoise rectangle.



Coronal and transverse localizer with navigator (turquoise window)

Positioning the navigator (II)

Navigator is displayed in graphic slice positioning	**Position the navigator in the localizers.** In the coronal localizer: at the edge of the diaphragm (upper half of navigator is in the lung, lower half is in the liver). In transverse localizer: on the dome of the liver.

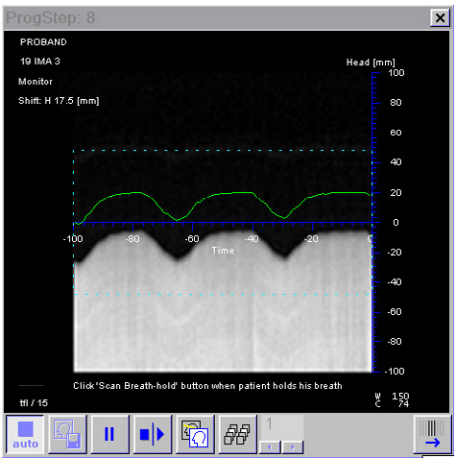


Correct positioning of the navigator

Checking the navigator position

Navigator is positioned

Prior to the measurement, go to the Inline Display and check whether the navigator is positioned correctly.



Accurate positioning of navigator: During normal breathing, the transition between the dark signal of the lung and the bright signal of the liver occurs in the navigator (turquoise window). The detected diaphragm position (green line) follows this edge.

Please note: The green line and the transition between liver/lung do *not* have to be congruent.

Correcting the position of the navigator

Terminate the measurement.

Track the navigator asymmetrically to the edge of the diaphragm.
This may be necessary, when, e.g., the localizer was generated while the patient was deeply inhaling or exhaling.

Example: The navigator is located completely in the liver (is located too far down).
The transition between the dark signal of the lung and the bright signal of the liver takes place above the turquoise window.

In this case, shift the navigator upward (toward the head).
The navigator in the localizer appears no longer symmetrical to the edge of the diaphragm.

TIP

You can also check the navigator positioning during a short control measurement that involves the respiratory curve only.
For this purpose select the **Scout Mode** option on the **Physio PACE** parameter card. Set the duration of the control measurement (Parameter **Scout Duration**).

NOTICE

Please note that the **Scout Mode** option *cannot* be selected during the actual measurement.

Performing the measurement

Navigator is positioned

The course of the examination is similar to a multi-breathhold measurement. However, in this case you have to select the **Breathhold&Follow** option in place of the **Breathhold** on the **Physio PACE** parameter card.

Start the measurement of the protocol.

The option **Wait for user to start** (flagman) in the **Protocol step properties** dialog box is not required and should *not* be selected for multi-breathhold protocols.

Open the Inline Display.
Start the first breathhold command as soon as "Press Scan in Inline Display when patient holds breath" appears to the bottom left in the measurement time display.

Multi-breathhold measurement > p. 84

Start the measurement after the patient is holding his breath.
For this purpose, click the “Scan Button” in the Inline Display.

The navigator image generated immediately before acquiring the slices of a breathhold interval is used to reduce the shift between slices measured during different breathhold intervals (comparative block method > p. 12).

The patient should wear the headset so he understands the breathhold commands despite gradient knocking. Navigator excitation is not used during actual measurement.

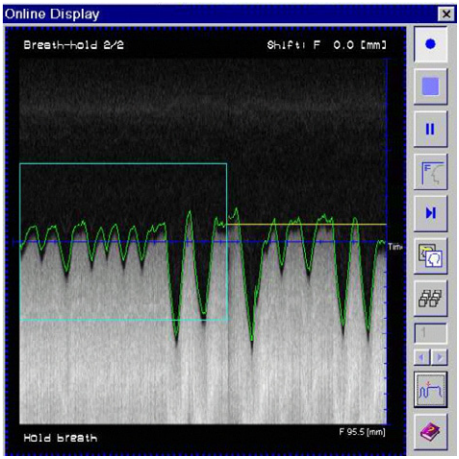
TIP

To monitor the patient's breathing before and during breathhold commands while the slice position remains unchanged, use the **Breathhold & Monitor** option. This corresponds to a tracking factor equalling zero, and/or an acceptance window equalling zero.

Respiratory curve in the Inline Display

Measurement is in progress

During the pauses prior to the first and between individual breathhold intervals, the navigator signal is repeated at regular intervals TR_{Scout}. These navigator images are used to display the respiratory curve in the Inline Display.



*Respiratory curve of the **Breathhold&Monitor** option with two breathhold intervals. The green curve does not correspond to the edge of the diaphragm. Only relative positions, but not the absolute diaphragm position is detected.*

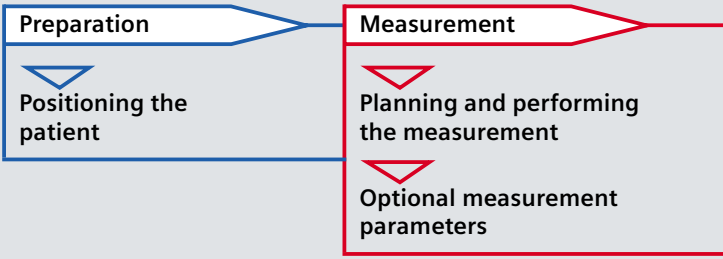
The respiratory curve is not continued during the breathhold interval. However, the green curve shows a red section that indicates the breathhold interval. During a perfect breathhold, the red section turns into a horizontal line (difficult to detect). What is noticeable, however, is deep inhaling and exhaling during the respiratory commands and taking a breath after the first breathhold interval.
After the first breathhold interval, the yellow horizontal line identifies the reference position. The position of the second breathhold interval (right image margin) deviates considerably from the reference position.

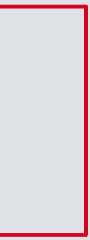
TIP
The time TR_{Scout} can be set on the parameter card **Physio PACE** (**Scout TR**).

TIP
The Breathhold & Follow option shows the acceptance window as yellow window in addition to the reference position. The slices are not tracked if the green curve does not fall within the acceptance window immediately before the breathhold interval.

Measuring with navigator gating

We are going to illustrate the most important steps of a navigator-gated examination. Data acquisition is performed during normal breathing.



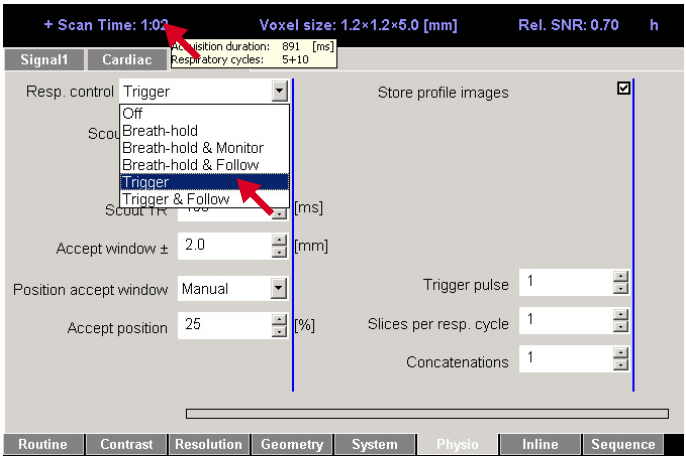


Planning and performing a navigator-gated measurement

Coronal localizer is available

Proceed as follows when planning a navigator-gated measurement:

Select the Trigger option under the respiratory control parameter on the Physio PACE parameter card.



The duration of acquisition is available as a tool tip of the measurement time. In line 2 you will find the number of required respiratory cycles (5 respiratory cycles for learning phase plus X respiratory cycles for the imaging phase).

Position the navigator in the localizers (positioning the navigator > p. 92).

Plan the slices.
Set the imaging parameters (e.g., number of slices per concatenation, Turbo factor) so that the duration of acquisition either equals or is reduced by 1/3 of the expected average respiratory period.

Please note: Cooperation of the patient is important during the learning phase of the examination.

Instruct the patient to breathe normally during the entire measurement (don't stop breathing).

Start the measurement.
Check the acquisition window during the learning phase.
For that purpose, monitor the width of the red rectangles on the Inline Display.

NOTICE

For healthy adults, the respiratory period (interval maximum inspiration to maximum inspiration) is approx. 4 – 6 s. However, this period may be shorter for children or the ill.

Reducing the acquisition duration > p. 24

Optional measurement parameters (I)

Trigger option is selected

In general you do not have to change the remaining parameters on the Physio PACE parameter card.

Accept window ±
Set the height of the yellow acceptance window in the Inline Display. No display during inspiration.

Position accept window
If **Automatic** has been selected, the system sets the center of the acceptance window during the learning phase.
In the **Manual** mode, you can set the value in percentages (%) under **Accept position**.

Accept position
Shift the center of the acceptance window between the mean end expiration (0%) and the mean end inspiration (100%)

Slices per respiratory cycle
Number of slices per respiratory cycle.
Is supported by HASTE, trueFISP and TurboFLASH sequences.

Cardiac trigger/ respiratory cycle
Number of cardiac gating per respiratory cycle (during double gating)

Trigger pulse
For *n* value, *n – 1* respiratory cycles are omitted between neighboring gates. Normally, the parameter is set to a minimum to minimize the measurement time.

Double gating
Proceed as follows for a combined cardiac-gated examination.

Select the Trigger option under the respiratory control parameter on the Physio PACE parameter card.

Select the desired gating signal on the Physio Signal 1 parameter card (e.g. ECG/Trigger).
Set the other parameters (acquisition window, trigger delay) as usual.

Optional measurement parameters (II)

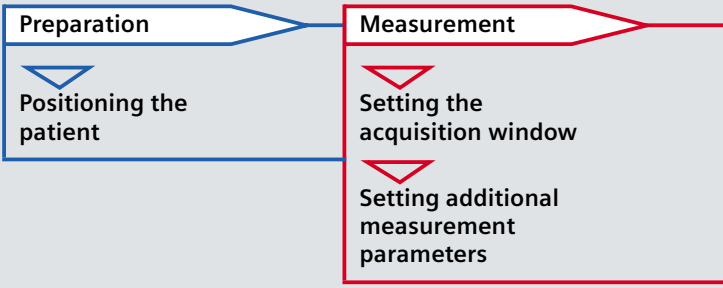
Measuring the respiratory period

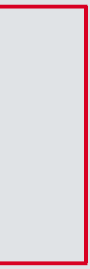
Select the Scout mode option and start the measurement.
After a complete respiratory interval (at least two end expirations) the average respiratory period is shown in the Inline Display (respiratory cycle).

Please note: The **Scout mode** option *cannot* be selected during the actual measurement.

Measuring with respiratory gating

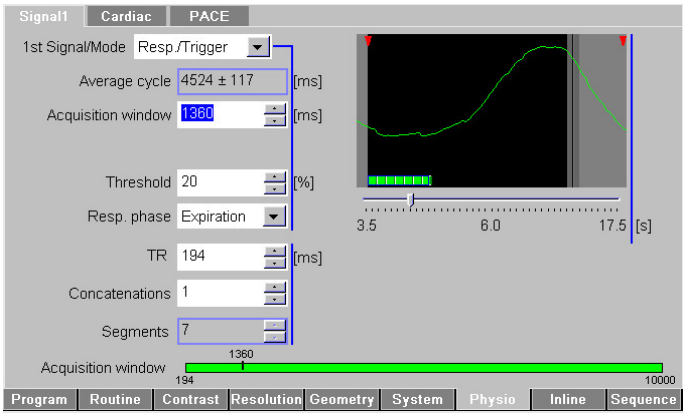
We would like to show you the most important steps involving respiratory gating. Particular events occurring with T1-weighted measurements using gradient echo sequence gre are mentioned explicitly.





Setting the acquisition window

The display of the respiratory signal on the **Physio** parameter card facilitates correct setting of the acquisition window.



Acquisition window during exhalation of the respiratory period

Select the acquisition window as large as possible to reduce the measurement time.
However, to avoid motion artifacts, limit yourself to the exhaled, relative motionless area of the respiratory period.

Duration of the acquisition window

The duration of the acquisition window is a compromise between reducing the examination time (large acquisition window) and the best possible insensitivity to motion artifacts (small acquisition window).

The duration of the acquisition window depends on the average respiratory period of the patient. It should include between 1/3 and max. 1/2 of the average respiratory period.

T1-weighted measurement with gre

To keep the examination time as short as possible, the sequence automatically selects the largest possible number of segments for a given acquisition window.

Setting additional parameters for T1-weighted measurements

Saturation

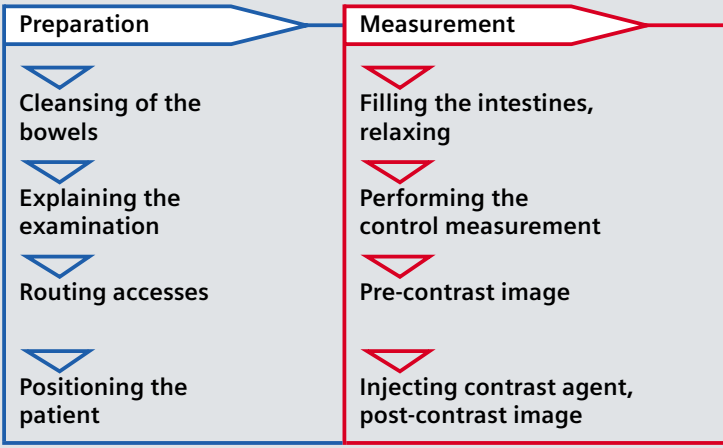
In case you would like to use saturation pulses, select the Quick saturation mode.
This shortens the measurement time.

Number of averages

If your are using several averages, select the long term averaging mode.
Motion artifacts are suppressed as well.

Performing dark lumen colonography

In what follows we are providing an overview including preparation as well as the procedure involving dark lumen colonography.




Post-processing
Evaluating images

Preparing dark lumen colonography

Preparation includes full cleansing of the bowels the day before the examination followed by one night of fasting.

Cover the entire examination with the patient.
Explain the filling of the intestines with water.
Practice holding one's breath with the patient.

Position the patient on his side on the patient table.

Position the inflow for filling the intestines with water.

Move the patient into the prone or supine position.

Prepare an I.V.

Move the patient table into the magnet bore and center the region to be examined in the magnet iscocenter.

Performing dark lumen colonography

Patient is positioned

Pre- and post-contrast images are measured for dark lumen colonography.

Begin to fill the intestines with water.

Inject medication for relaxing the intestines.

Check the filling and expansion of the large intestines by using a TrueFISP or HASTE sequence.

As soon as the intestines are filled and sufficiently expanded, perform a native 3-D VIBE sequence with respiratory gating.

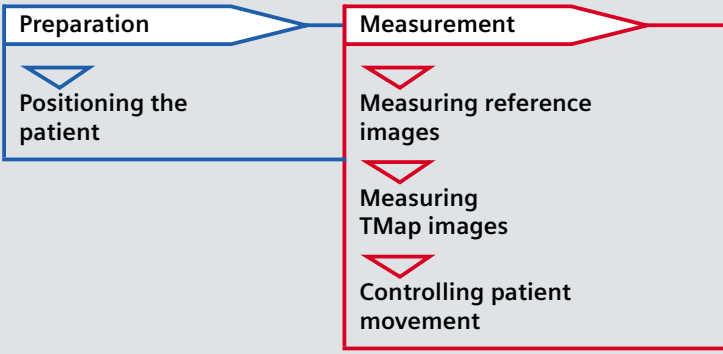
Inject contrast agent.

Repeat the 3-D VIBE sequence 75 seconds after administering contrast agent.

Evaluate the images (MIP, MPR, VRT).

Displaying temperature changes

For displaying changes in temperature (≥ 15° C), you generate reference images once prior to heating and TMap images continuously or as required during heating. You are then able to monitor temperature changes in the subtraction images.



Coils:
Use the Body Matrix or the Spine Array Coil for the uterus.

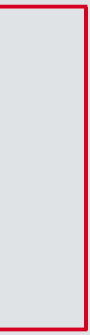
Safety aspects > p. 76

PROTOCOL

Localizer

gre_ref

gre_TMap



Measuring reference images

Localizer is available

Prior to heating, you are generating reference images.

Select the reference protocol (gre_ref).
If necessary, adjust the protocol parameters.

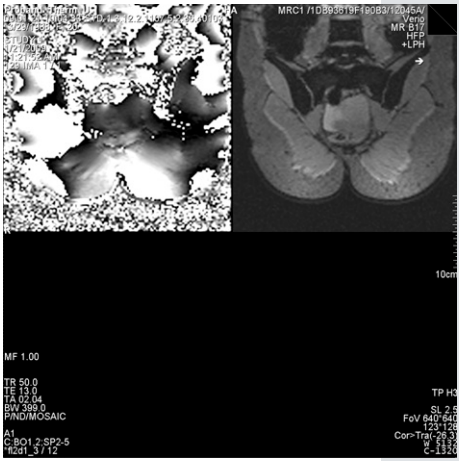
Setting TE
The echo time affects the temperature accuracy of the measurements.

Select TE so that it approximates T2*.
However, TE should not be greater than:

- 13 ms (1.5 T)
- 10 ms (3 T)

Start the reference measurement.

The phase and magnitude images that have been measured are shown in the Inline Display.



Please note: Ensure that the images display the region to be heated.

Measuring TMap images

Reference images are available

You are now heating up the tissue and begin measuring the TMap images.

Please note: The heating should lead to a temperature difference of ≥ 15° C. Even smaller temperature changes not visible in the image, may damage tissue!

Select the gre_TMap protocol.
In case you changed the measurement parameters after the reference measurement:

Copy the sequence parameters from the reference protocol. (Queue > Copy parameter)

Correcting the magnetic field B0
When taking a large number of measurements, the magnetic field may drift. In this case, correct the B0 with a navigator.
Select one navigator.
(**Parameter card Geometry > Navigator**)

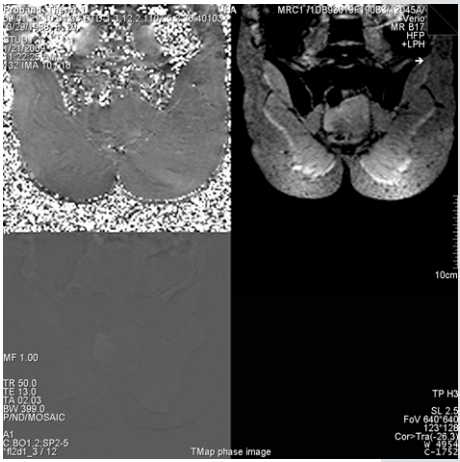
Position the navigator on a region located in the slice to be measured. Ensure that the region does not show temperature changes, e.g., in the back.

Start measuring the TMap images.

The Inline Display shows the phase, magnitude, and subtraction images that have been measured.

TIP

In case you started the measurement without reference images or retroactively shifted slices, the measurement will be automatically terminated. Should this happen, please repeat the reference measurement.



On top, to the left: phase difference image, temperature changes would appear as bright areas

Checking patient movement

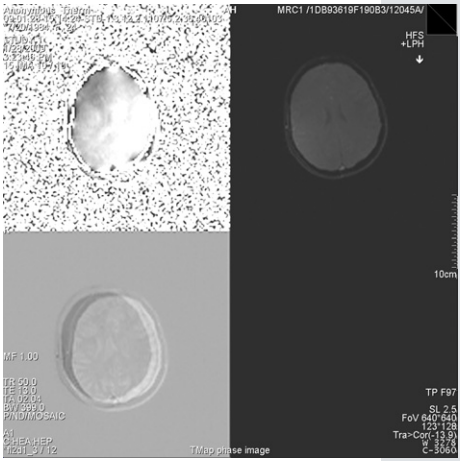
Subtraction image is available

The technique introduced in these pages is only a reference and not an absolute method. For this reason, patient movements that occur between generating reference and TMap images may lead to strong distortions in the phase difference images and consequently to errors in the TMap images.

The last image in the Inline Display shows a subtraction image from the reference image (taken at the beginning of the examination) and the current TMap image.

Check whether the subtraction image in the region of interest shows large changes.

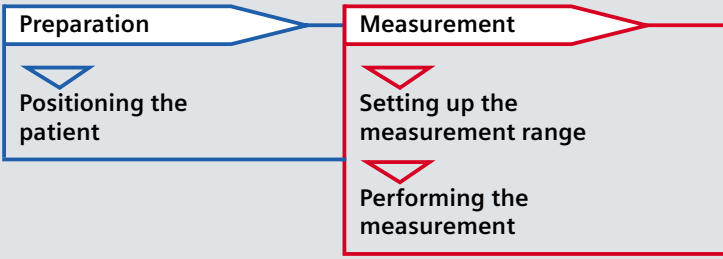
If it does, repeat the examination in full. Allow for sufficient tissue cooling before starting the new measurement.

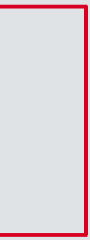


Example head:
Noticeable effects created by patient movement in the subtraction image (bottom left) as well as in the phase image (top left)

Tumor identification with TimCT Oncology

Examinations with TimCT Oncology can be combined with multi-breathhold measurements to avoid motion artifacts.





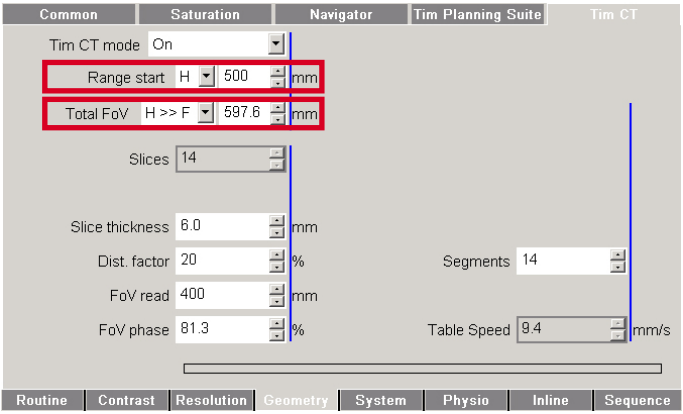
Setting up the measurement range

Localizer available

You determine the number of slices to be measured using the size of the measurement range.

On the **Geometry-TimCT** parameter card:

Select the start position (Range start) and the length of the measurement range (total FoV).



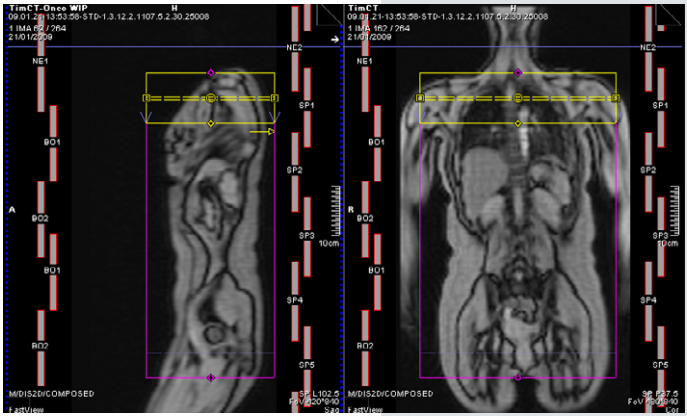
Please note: The measurement requires continuous adjustments and an acceleration region for the patient table. For this reason, approx.10 cm of signal-emitting material should be available at both ends of the measurement range.

As a next step, set the parameters requested for table movement.

The settings are applied to all slice groups of the measurement range.

TIP

To avoid additional inline adjustments:
plan a generous FastView localizer.



Slice groups in the graphic slice positioning (GSP) mode.
The blue line shows the start position of the table movement

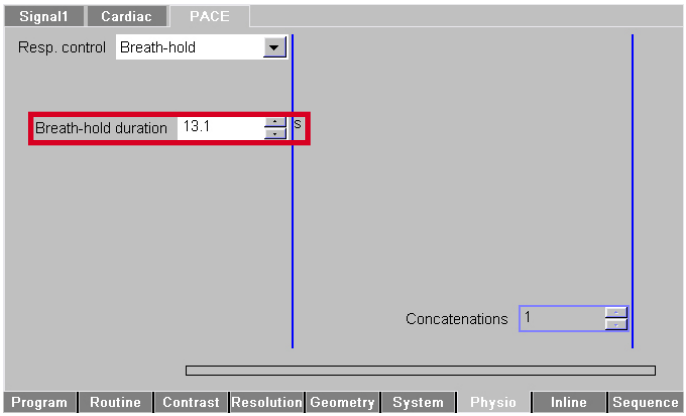
Performing multi-breathhold measurements

Measurement range is set

You can divide the total measurement times into breathhold intervals of arbitrary length using the Inline Display.

In the parameter card **Physio-PACE**:

Enter the patient-specific breathhold duration.

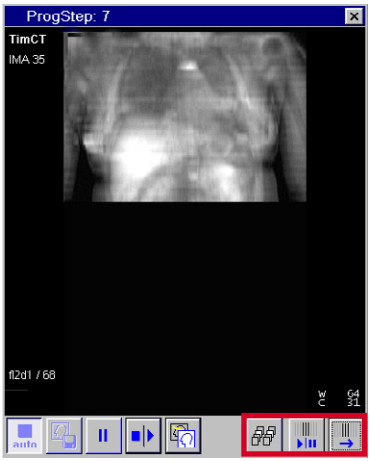


Start the measurement.
Open the Inline Display.

Measure the entire measurement range in several steps.
(Scan breathhold in the Inline Display)


Toggles between anatomical and projection progress images. (**Display Filter**)


Continues measurement in regions without respiratory motion. (**Scan/pause**)



TIP

Prior to the last breathhold measurement or for **Scan/pause**: To avoid interrupting the measurement at the end of the examination, instruct the patient to continue holding his breath as long as possible and then continue with shallow breathing.

TIP

As compared to conventional breathhold measurements, the measurement data are shared from various breathhold intervals (exception: measurements using haste). For this reason, ensure the best possible reproducibility of the breathhold status.

2-D PACE 10
Time-dynamic imaging 44

A Abdominal MR imaging
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