Pulse Sequences

Application Brochure

MAGNETOM Aera, Avanto, Skyra, Verio, Avanto^{fit}, Skyra^{fit}

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This brochure informs the user about the pulse sequences of *syngo* MR for the MR tomographs listed on the front page. It addresses medical personnel working in the area of MR tomography.

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Overview

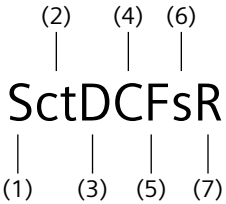
The MR systems are equipped with optimized pulse sequences that allow for highly flexible adjustments to meet your clinical requirements.

Parameter ranges	The sequences cover a broad range of parameters and allow for flexible timing (exception: flow-compensated spin echo sequences that have a slightly limited parameter range).

Sequence variants

The sequence variants are shown via the parameter card (in the protocol info line) and in the image text. The variant comprises:

- the sequence type (e.g., se for spin echo), and
- the expansions based on the parameters selected



(1) = Sequence type
(2) = Continuous table move
(3) = Dimension
(4) = Number of contrasts
(5) = Flow compensation
(6) = Number of segments of combined echoes
(7) = Excitation pulse

On-screen display

The sequence variants are shown in different ways on-screen.

- In the image text: The *complete* sequence variant is displayed (e.g., fl3d1r_tf)
- In the parameter card: Only the *abbreviation* of the sequence variant is shown (sequence code)

Example: fl_r = FLASH sequence with flow compensation in the readout and slice selection direction.

Displaying the complete sequence variant
Position the mouse pointer on the sequence code.
The sequence variant is shown in full.

Sequence variant components (I)

Sequence type (S)

Abbreviation	Definition
ci	CISS (Constructive Interference in Steady State)
csi	Chemical shift imaging
de	DESS (Dual Echo Steady State)
epfid	EPI-FID
epir	EPI spin echo with inversion recovery
epse	EPI spin echo
fi	FISP (Fast Imaging with Steady State), gradient echo sequence without RF spoiling
fid	Free induction decay
fl	FLASH (Fast Low Angle Shot), gradient echo sequence with active RF spoiling
h	HASTE (Half Fourier Single Shot TurboSE)
hir	HASTE with inversion recovery
ir	Spin echo with inversion recovery
me	MEDIC (Multi Echo Data Image Combination)
ps	PSIF (time-reversed FISP)
resolve	RESOLVE (REadout Segmentation Of Long Variable Echo trains), multi-shot, diffusion-weighted EPI

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Sequence type (S)

Abbreviation	Definition
se	Spin echo
spc	SPACE (Sampling Perfection with Application-optimized Contrast using different flip angle Evolutions)
svs	Single voxel spectroscopy
swi	Susceptibility-weighted imaging
tfl	TurboFLASH
tgir	Turbo gradient spin echo with inversion recovery
tgse	Turbo gradient spin echo
tir	Turbo spin echo with inversion recovery
tirB	Turbo spin echo with inversion recovery and BLADE trajectory
tirBR	Turbo spin echo with inversion recovery, BLADE trajectory and "restore pulse"
tirR	Turbo spin echo with inversion recovery and "restore pulse"
tse	Turbo Spin Echo
tseB	Turbo spin echo with BLADE trajectory
tseBR	Turbo spin echo with BLADE trajectory and "restore pulse"
tseR	Turbo spin echo with "restore pulse"

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Sequence variant components (II)

Dimension (D)

Abbreviation	Definition
1d	1-dimensional data acquisition
2d	2-dimensional data acquisition
3d	3-dimensional data acquisition

Contrast (C)

Abbreviation	Definition
1, 2, ..., 16, ...	Number of reconstructed images with different contrasts

Flow compensation (F)

Abbreviation	Definition
r	Flow compensation in the readout and slice selection direction
rr	Flow compensation in the readout direction only
rs	Flow compensation in the slice direction only
rd	Interleaved acquisition with alternating rephased and dephased measurements.
–	No flow compensation; is displayed only if another character follows
pc	Flow-sensitive gradients for phase-contrast angiography

Number of segments or combined echoes (s)

Abbreviation	Definition
2, 3, ..., 15, ...	Number of segments in the k-space for segmented sequences: EPI factor × Turbo factor × segments
2, 3, 4, 5, ...	Medic sequences: Number of combined echoes
–	If the number of segments = 1 and the number of combined echoes = 1 (is shown only, if another character follows)

Excitation pulse (R)

Abbreviation	Definition
ns	Non-selective excitation
t10, t20, ..., t100	TONE pulse; number indicates the value of the TONE ramp parameter (in percent)

Sequence nomenclature (I)

The sequence nomenclature is used in the *syngo* database. It is shown, for example, in the Siemens sequence binder.

Abbreviation	Definition
ciss	Constructive Interference Steady State
dess	Dual Echo Steady State
ep	Echo Planar Imaging
fl	FLASH (fast low angle shot)
gre	Gradient echo sequence
haste	Half Fourier Single Shot Turbo Spin Echo
medic	Multi-Echo Data Image Combination
psif	Time inverted FISP sequence (FISP = fast imaging with steady state precession)
se	Spin echo sequence
tfl	TurboFLASH
tgse	Turbo gradient spin echo
trufi	TrueFISP (FISP = fast imaging with steady state precession)
tse	Turbo spin echo

Abbreviation	Definition
_bold	Sequence for BOLD imaging (BOLD = Blood Oxygen Level Dependency)
_cb	For determining the contrast bolus
_ce	For contrast-enhanced angiography
_ct	For angiography with continuous table move
_diff	Sequence for diffusion contrast
_fid	Free induction decay, e.g., ep_fid: Gradient echo variant of EPI sequence
_field_mapping	For generating a field map for BOLD post-processing
_fq	Flow quantification
_IRT	Sequence for interactive real-time imaging
_mc	Multi-contrast sequence
_nav	Sequence with navigator
_pace	Sequence with prospective motion correction
_pasl	Sequence for perfusion imaging (PASL = Pulsed Arterial Spin Labeling)
_pc	Phase-contrast angiography
_peri_tof	Time-of-Flight sequence, optimized for peripheral angiography
_r	With flow compensation
_rd	Rephased-dephased angiography sequence

Sequence nomenclature (II)

Abbreviation	Definition
_se	Spin echo sequence, e.g., ep_se: Gradient echo variant of EPI sequence
_seg	Segmented sequence, also refer to ..seg..
_sheco	Shared echo sequence (double contrast TSE)
_shphs	Shared phases sequence
_slaser	Semi-LASER variant
_st	Spectroscopy sequence for STEAM technique (STEAM = Stimulated Echo Acquisition Method)
_tof	Time-of-Flight (inflow angiography)
_trufi	TrueFISP (FISP = fast imaging with steady state precession), refer to trufi as well
_vibe	Volume interpolated breathhold examination
_vfl	Variable flip angle

Abbreviation	Definition
..b..	Bandwidth per pixel; the value follows in Hertz, e.g., se_15b130
..perf..	To measure First Pass perfusion
..r..	With flow compensation, also refer to _r
..seg..	Segmented sequence, also refer to _seg
..ti..	To determine TI (cardiac imaging)
..2d	2D imaging
..3d	3D imaging
.._15..	Echo time, e.g., 15 ms

Basic sequences: Spin echo with fixed temporal sequence, sequence description

The basic sequences are a full set of sequences for clinical routine examinations.
The temporal sequence of the following spin echo sequences is fixed, that is, *independent* of the parameters selected.

Single contrast sequences

Recommendations: The contrast is optimized as a function of TR by varying the flip angle. With a short TR (<500 ms), you can improve T1 contrast by reducing the flip angle to 70 degrees. However, the signal-to-noise ratio is slightly reduced.

se_15b130

Classic spin echo sequence without flow compensation.
Use
T1 weighting.

se_17rb130[a]

Flow-compensated spin echo sequence.
Use
Post-gadolinium applications in the head.

[a] only available at systems with a field strength of 1.5 T

	se_15b130	se_17rb130[a]
TE variable	✓	–
Contrasts	1	1
Magn. Prep.	IR	IR
Recon. mode	Magnitude/Real[b]	Magnitude/Real[b]
Fat suppression	Fat saturation/ water excitation	Fat saturation
Saturation regions	Regular/Parallel	Regular/Parallel
MTC	✓	✓
Phase Partial Fourier	✓	✓
Averaging mode	Short term/ long term	Short term/ long term
Multi-slice mode	Interleaved/ sequential	Interleaved/ sequential
Flow comp.	No	Yes
Dimension	2D	2D
RF pulse type	Normal	Normal
Gradient mode	Normal	Normal

[b] may be selected only if Magn.Preparation = IR has been selected

Basic sequences: Spin echo with optimized temporal sequence, sequence description

In these sequences, the temporal sequence *depends* on the parameters selected.

se

Spin echo sequence without flow compensation.

Use

As a single contrast sequence, especially well suited for T1-weighted imaging regardless of the body region selected.

Recommendations: Select RF pulse type "Low SAR" to avoid exceeding the SAR limit.

Use

Dark blood imaging for examining cardiac anatomy by adding dark blood preparation.

se_mc

Multi-contrast sequence with up to 32 contrasts. The sequence design is derived from the TurboSE technique. Since stimulated echoes contribute to the signal with TurboSE, the second echo provides a higher signal contribution than the first echo.

Use

For acquiring T2 relaxation curves.

Recommendations: For T2 image reconstruction, do *not* use the first echo in the calculation.

Basic sequences: Spin echo with optimized temporal sequence, parameter ranges

	se	**se_mc**
TE variable	✓	✓
Contrasts	1–2	1–32
Bandwidth variable	✓	✓
Magn. Prep.	IR	IR
Recon. mode	Magnitude/Real[a]	Magnitude/Real[a]
Fat suppression	Fat saturation/ water excitation/ SPAIR	Fat saturation
Saturation regions	Regular/Parallel	Regular/Parallel
MTC	✓	✓
Phase Partial Fourier	✓	✓
Asymm. Echo	Off/allowed	–
Averaging mode	Short term/ long term	Short term/ long term
Multi-slice mode	Interleaved/ sequential	Interleaved/ sequential
Flow compensation	No	No
Dimension	2D	2D

	se	se_mc
RF pulse type	Fast/Normal/ Low SAR	Fast/Normal/ Low SAR
Gradient mode	Fast/Normal/ Whisper	Fast/Normal/ Whisper
Dark blood	✓	✓
Multi-breathhold	✓	–
MapIt	–	✓
Blood suppression	On/off	–

[a] may be selected only if Magn.Preparation = IR has been selected

Basic sequences: Turbo spin echo, sequence description (I)

tse

At a turbo factor of 1, the sequence behaves like a spin echo sequence.

Recommendations: If SAR is exceeded, either the flip angle of the refocusing pulse can be reduced and/or RF pulse type "Low SAR" can be selected. A smaller flip angle (e.g., approx. 150°) does not have a noticeable effect on image contrast. As an alternative, the hyperecho technique[a] may be used for SAR reduction.

Use

T1/T2/PD weighting for neuro and ortho imaging with high resolution.
Multislab 3D TurboSE in the neuro area.
Restore technique available.
BLADE technique available.
Evaluation of metastases and lymph nodes in the thorax, abdomen, and pelvis.

[a] only available at systems with a field strength of 3 T

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Recommendations 3D: Slab distance 0, 2 concatenations, 50% oversampling in the slice selection direction. Isotropic resolution is obtained, and any view can be reconstructed using MPR.

Use

Dark fluid neuro imaging.

Recommendations: Select 2 concatenations. This prevents differences in brightness of adjacent slices and suppresses inflow effects from CSF.

Use

Inversion recovery neuro imaging with magnitude or real part image display for pediatric diagnostics.

T2 weighting for breathhold studies in abdominal imaging.

Basic sequences: Turbo spin echo, sequence description (II)

tse (continued)

Recommendations: High turbo factor, RF pulse type "Fast", high readout bandwidth.

Use

Dark blood imaging for examining cardiac anatomy.

Use

T2 weighting for neuro imaging with Restore technique.

Recommendations: For 3D imaging use a TR >500 ms to obtain good CSF contrast. To prevent loss of signal due to flow phenomena, switch on flow compensation in either the slice selection or readout direction.

Reducing image distortions

MR-conditional implants[a] may cause strong off-resonance artifacts. To reduce the artifacts, select the WARP parameter.
Use WARP in combination with a high readout bandwidth (approx. 300–500 Hz/Pixel) and a small slice thickness.

[a] Please adhere to all safety instructions regarding implants (-> Operator Manual - MR System)

If VAT[b] is selected in addition, image distortions can be further reduced. However, VAT may introduce some blurring in the image. To reduce VAT-related blurring, increase the readout bandwidth and reduce the slice thickness. The VAT effect can be scaled from 0% (no VAT) to 100% (full VAT).
The appropriate VAT value depends on the level of artifacts and their effect on the anatomic region of interest. In general, a higher level of artifacts requires a higher VAT value.
Do not use conventional spectral fat suppression (including SPAIR) in the presence of strong off-resonance effects, use inversion recovery based fat suppression (STIR) instead.

[b] VAT: View Angle Tilting technique, eliminates the signal shift in the frequency-encoding direction caused by off-resonance effects

MR imaging of patients with metallic implants brings specific risks. However, certain implants are approved by the governing regulatory bodies to be MR conditionally safe. For such implants, the previously mentioned warning may not be applicable. Please contact the implant manufacturer for the specific conditional information. The conditions for MR safety are the responsibility of the implant manufacturer, not of Siemens.

Basic sequences: Turbo spin echo, sequence description (III)

tse_sheco

Shared echo sequence.

Recommendations: If SAR is exceeded, either the flip angle of the refocusing pulse can be reduced and/or RF pulse type “Low SAR” can be selected. A smaller flip angle does not have a noticeable effect on image contrast.

Use

Multi-contrast.

Proton density/T2 double contrast sequence for neuro imaging.

Inversion recovery double contrast imaging with magnitude or real part image display.

[a] only available at systems with a field strength of 1.5 T

spc/tse_vfl

3D TurboSE sequence optimized for 3D data acquisition, T1/T2/PD weighting, and dark fluid contrast. Significant SAR reduction through the variable flip angle technique.

Use

SPACE applications.

Display of the entire head with high spatial resolution within an acceptable measurement time.

PD, PD FatSat and T1 weighting with high spatial resolution for orthopedic applications.

Basis for non-CE MR angiography protocols with NATIVE SPACE.[a]

[a] with NATIVE licencse

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Basic sequences: Turbo spin echo, sequence description (IV)

haste

Single-shot TurboSE sequence.

Use

T2 weighting for neuro applications, used, for example, with uncooperative patients.
T2 weighting for breathhold studies in the abdomen without motion artifacts.
Cholangiography imaging when using very long echo times (~1 s).
Myelography imaging when using very long echo times (~1 s).
Dark blood imaging for examining cardiac anatomy.
Restore technique available.
Evaluation of metastases and lymph nodes in the thorax, abdomen, and pelvis.

Recommendations: If SAR is exceeded, either the flip angle of the refocusing pulse can be reduced and/or RF pulse type "Low SAR" can be selected. A smaller flip angle (e.g., approx. 150°) does not have a noticeable effect on image contrast. As an alternative, the hyperecho technique[a] may be used for SAR reduction.

[a] only available at systems with a field strength of 3 T

Basic sequences: Turbo spin echo, parameter ranges (I)

	tse	**tse_sheco**
Turbo factor	1–129	5–7
TE variable	✓	✓
Contrasts	1–3	1–2
Bandwidth variable	✓	✓
Magn. Prep.	IR	IR
Recon. mode	Magnitude/Real[b]	Magnitude/Real[b]
Fat suppression	Fat saturation/ SPAIR	Fat saturation
Dixon	✓	–
Saturation regions	Regular/Parallel	Regular/Parallel
MTC	✓	✓
Phase Partial Fourier	✓[c]	✓
Averaging mode	Short term/ long term	Short term/ long term
Multi-slice mode	Interleaved/ sequential	Interleaved/ sequential
Flow compensation	No/Readout/Slice	No/Readout/Slice
Dimension	2D/3D	2D
Elliptical scanning[a]	✓	–
Slice resolution[a]	✓	–
Slice Partial Fourier[a]	✓	–

	tse	tse_sheco
RF pulse type	Fast/Normal/ Low SAR	Fast/Normal/ Low SAR
Gradient mode	Fast/Normal/ Whisper	Fast/Normal/ Whisper
Dark blood	✓	✓
iPAT	✓	–
Multi-breathhold	✓	–
2D PACE	Multi-breathhold/ Trigger	–
Hyperecho	✓	–
BLADE Trajectory	✓	–
Restore	✓	–
TimCT mode	On/off	–
WARP	✓	–
VAT[d]	0–100%	–

[a] only if Dimension = 3D is selected

[b] may be selected only if Mag. Preparation = IR has been selected

[c] parameter cannot be freely set, depends on selected TE

[d] only if WARP is selected

Basic sequences: Turbo spin echo, parameter ranges (II)

	spc/tse_vfl	**haste**
Turbo factor	9–511	1–512[d]
TE variable	✓	✓
Contrasts	1	1–2
Bandwidth variable	✓	✓
Magn. Prep.	IR, DIR	IR
Recon. mode	Magnitude/Real[b]	Magnitude/Real[b]
Fat suppression	Fat saturation/ SPAIR	Fat saturation/ SPAIR
Saturation regions	Regular/Parallel	Regular/Parallel
MTC	✓	✓
Phase Partial Fourier	✓[c]	✓[c]
Averaging mode	Short term	Long term
Multi-slice mode	–	Single-shot
Flow compensation	No/Readout	No
Dimension	3D	2D/3D
Elliptical scanning	✓	–
Slice resolution	✓	✓[a]
Slice Partial Fourier	✓	✓[a]
RF pulse type	Fast/Normal/ Low SAR	Fast/Normal/ Optimized

	spc/tse_vfl	haste
Gradient mode	Fast/Normal/ Whisper	Fast/Normal/ Whisper
Dark blood	–	✓
iPAT	✓	✓
iPAT[2]	✓	–
Multi-breathhold	–	✓
2D PACE	✓	Multi-breathhold/ Trigger
Restore	✓	✓
TimCT mode	–	On/off
NATIVE[e]	Off/TD scout/ 3D mode	–
Flow sensitivity[e]	Default/Weak/ Medium	–

[a] only if Dimension = 3D is selected

[b] may be selected only if Mag. Preparation = IR has been selected

[c] parameter cannot be freely set, depends on selected TE

[d] parameter cannot be freely set, depends on base and phase resolution

[e] with NATIVE license; "NATIVE" available only in case of ECG or pulse trigger, "Flow sensitivity" available only if NATIVE is not off

Basic sequences: Gradient echo, sequence description (I)

RF spoiling can be activated with gradient echo sequences. FLASH contrast is generated when RF spoiling is switched on, FISP contrast when RF spoiling is switched off.

gre

Gradient echo sequence

Use

T1 weighting for breathhold studies in abdominal imaging.

Recommendations: Quick parallel sat enables saturation of inflowing blood without significantly increasing measurement time. Quick Fatsat enables fat saturation without significantly increasing measurement time. Water excitation enables fat suppression within acceptable TR increase. Disadvantage: TE is prolonged.

Use

Abdominal imaging In-phase Opposed-phase in one measurement.
3D FLASH sequence for T1-weighted ortho imaging and neuro imaging.
Fast 3D sequence for contrast agent enhancement studies.
Segmented CINE FLASH sequence, can be combined with line or grid tagging.
Susceptibility-weighted imaging (SWI).
Evaluation of metastases and lymph nodes in the thorax, abdomen, and pelvis.

Susceptibility-weighted imaging > p. 140

Basic sequences: Gradient echo, sequence description (II)

FastView Gradient echo sequence

Use

For overview images of large body regions with transverse slices and continuous table move.

Parameter ranges

	1.5 T	**3 T**
Matrix	96	96
Slice thickness	5 mm	5 mm
TE/TR	2.19 ms/3.31 ms	1.44 ms/2.56 ms
FoV	480 mm × 87.5%	480 mm × 87.5%
Table speed	36 mm/s	46 mm/s

medic

MEDIC sequence (Multi Echo Data Image Combination), gradient echo sequence with flow compensation. When combined echoes = 1, the sequence behaves like a FLASH sequence with flow compensation.

Use

T2*-weighted imaging with a high signal-to-noise ratio for the spine (especially transverse cervical and thoracic spine) and ortho (knee and shoulder) imaging.

T2*-weighted 3D imaging of the cervical spine with a small flip angle and adjusted TR.

Basic sequences: Gradient echo, sequence description (III)

tfl

Single-shot TurboFLASH sequence.

Use

- 3D tfl (= MPRAGE) for fast T1-weighted volume measurements of the head.
- 3D tfl with double inversion contrast (= MP2RAGE) for homogenous T1-weighted head imaging with high CNR and optionally T1 mapping. Activated by setting two IR contrasts.
- 2D tfl with dark blood preparation for low resolution imaging of the cardiac anatomy.
- 2D tfl combined with saturation recovery preparation for contrast agent enhancement studies.
- 2D tfl to determine the transit time of a test bolus as preparation for CE angiography.

Please note: The 3D tfl MP2RAGE protocols are optimized for consistent T1 mapping in the range of biological T1 values in the human tissue. Mapping of T1 values exceeding the range between 400 ms and 1800 ms becomes increasingly imprecise. T1 maps are presented along with a color bar that displays the color mapping between 0 and 2000 ms according to the current window levels. Computed T1 maps, however, may contain values between 0 and 4095 ms, thus exceeding the range of the color bar.

Recommendations: To prevent saturation effects, use the "long term" averaging mode. All slices will then be measured sequentially for one averaging, before the next averaging measures the series of slices again.

Basic sequences: Gradient echo, sequence description (IV)

tfl (continued)

Inline quality assessment for 3D tfl measurements of the head

The Inline quality assessment provides an overall image quality rating of 3D MPRAGE brain scans optimized for brain imaging. The approach is based on a careful analysis of the air background noise distribution. The background noise appears corrupted in the presence of patient related artifacts and renders the method primarily sensitive to subject motion. A landmark-based method is used to detect the presence of aliasing artifacts. The image quality of 3D MPRAGE volumes is rated as either “high”, “to be confirmed” or “not assessed” (see section “Outputs” below). It is enabled through the Morpho add-in. A default protocol is available in the Siemens protocol tree (\\SIEMENS\head\library_3D).

Parameter ranges	
Slice thickness	≤ 3 mm
Row and column spacing	≤ 2 mm
iPAT acceleration factor	≤ 3
In-plane matrix size	≥ 96 × 96
Number of slices	≥ 64
Orientations	Sagittal: A>>P or P>>A PE-direction Coronal: R>>L or L>>R PE-direction

In case of selective excitation, aliasing artifacts detection is not performed.

The functionality is disabled if "Head" coil is not selected.

Outputs

The overall quality rating is displayed in the image text of the original series.

Image quality	
High	in the case of a high-quality scan
Not assessed	in the case of non-performed quality assessment (i.e., inconsistent protocol parameters, error detected during the processing)
To be confirmed	if quality criteria are not fulfilled (e.g., motion, aliasing artifacts and other image degradations)

Basic sequences: Gradient echo, parameter ranges (I)

	gre
Segments	1–127
Combined echoes	–
TE variable	✓
Contrasts	1–12
Bandwidth variable	✓
Magn. Prep.	IR, SR[a]
Reconstruction mode	Magnitude/Phase
Fat suppression	Fat saturation/ water excitation
Saturation regions	Regular/Parallel/Tracking
MTC	✓
Phase Partial Fourier	✓
Asymm. Echo	✓
Averaging mode	Short term/long term
Multi-slice mode	Interleaved/sequential
Flow compensation	Yes/No/Readout/Slice/ Slice&Readout
Dimension	2D/3D
Elliptical scanning[b]	✓
Slice resolution[b]	✓

	gre
Slice Partial Fourier[b]	✓
Excitation pulses[b]	Slab-selective
RF pulse type	Fast/Normal
RF spoiling	On/off
Gradient mode	Fast/Normal/Whisper
Dark blood	✓[a]
Grid/line tagging	✓
iPAT	✓
iPAT[2]	✓
Multi-breathhold	✓
2D PACE	Multi-breathhold
Readout mode	Monopolar/Bipolar
SWI	✓
PACE	✓
MapIt	✓
TimCT mode	On[d]/off

[a] if segments >1 (segmented TurboFLASH)

[b] only if Dimension = 3D is selected

[c] may be selected only if Mag. Preparation = IR has been selected

[d] when switched on, DIXON reconstruction can be selected

Basic sequences: Gradient echo, parameter ranges (II)

	medic	**tfl**
Segments	–	–
Combined echoes	1 – 12	–
TE variable	✓	Min.
Contrasts	1	1
IR contrasts	1	2[f]
Bandwidth variable	✓	✓
Magn. Prep.	–	IR, SR
Recon. mode	Magnitude	Magnitude/Real[c]
Fat suppression	Fat saturation/ water excitation	Water excitation
Saturation regions	Regular/Parallel	–
MTC	✓	–
Phase Partial Fourier	✓	✓
Asymm. Echo	–	✓
Averaging mode	Short term/ long term	Long term
Multi-slice mode	Interleaved/ sequential	Single-shot
Flow compensation	Yes	No
Dimension	2D/3D	2D/3D

	medic	tfl
Elliptical scanning[b]	✓	✓[e]
Slice resolution[b]	✓	✓
Slice Partial Fourier[b]	✓	✓
Excitation pulses[b]	Slab-selective	Slab-selective/ non-selective
RF pulse type	Fast/Normal	Fast/Normal
RF spoiling	On/off	On/off
Gradient mode	Fast/Normal/ Whisper	Fast/Normal/ Whisper
Dark blood	–	✓
3D centric reordering	–	✓
Grid/line tagging	–	–
iPAT	✓	✓
iPAT[2]	–	–
Multi-breathhold	–	✓
2D PACE	–	Multi-breathhold/ Trigger
MapIt	–	✓

[a] if segments >1 (segmented TurboFLASH)

[b] only if Dimension = 3D is selected

[c] may be selected only if Mag. Preparation = IR has been selected

[d] only if Dimension = 2D is selected

[e] freely selectable if 3D centric reordering is activated

[f] may be selected only if Mag. Preparation = IR or SR has been selected

Basic sequences: Steady-state gradient echo, sequence description

With steady-state sequences, echo times TE and repetition times TR are set to fixed minimum values to ensure the best possible image quality. In case of the psif sequence, this applies to TE only, TR is a freely-adjustable parameter.

psif

Gradient echo sequence with flow compensation in slice or readout direction, but highly sensitive to motion artifacts. At a large flip angle, strongly T2-weighted images.

Use

T2-weighted imaging with 3D PSIF with flow compensation in readout direction, for CSF or spine diagnostics.

T2-weighted imaging with 2D or 3D PSIF with flow compensation in slice selection direction, for breathhold studies of the abdomen: Dark blood T2 weighting in the liver.

	psif
TE variable	Min.
Contrasts	1
Bandwidth variable	✓
Recon. mode	Magnitude
Fat suppression	Water excitation
Phase Partial Fourier	✓
Averaging mode	Short term/long term
Multi-slice mode	Sequential
Flow compensation	Readout/slice
Dimension	2D/3D
Elliptical scanning[a]	✓
Slice resolution[a]	✓
Slice Partial Fourier[a]	✓
Excitation pulses[a]	Slab-selective
RF pulse type	Fast/Normal
RF spoiling	Off
Gradient mode	Fast/Normal/Whisper
iPAT	✓
Diffusion weighting	Yes

[a] only if Dimension = 3D is selected

Basic sequences: TrueFISP, sequence description (I)

trufi

TrueFISP steady-state gradient echo sequence.

Recommendations: Minimize TR by selecting a high readout bandwidth to avoid interference streaks in the image.

Use

T2 weighting for neuro applications, used, for example, with uncooperative patients.
T2 weighting for breathhold studies in the abdomen without motion artifacts.

TE variable	Min.
Contrasts	1
Bandwidth variable	✓
Magn. Prep.	IR, SR
Reconstruction mode	Magnitude
Fat suppression	Fat saturation/ water excitation
Phase Partial Fourier	✓
Asymm. Echo	✓
Averaging mode	Short term/long term
Multi-slice mode	Sequential
Flow compensation	No[a]
Dimension	2D/3D
Elliptical scanning[b]	✓
Slice resolution[b]	✓
Slice Partial Fourier[b]	✓
Excitation pulses[b]	Slab-selective
RF pulse type	Fast/Normal
RF spoiling	Off
Gradient mode	Fast/Normal/Whisper
iPAT	✓
iPAT^{2} [b]	✓
Multi-breathhold	✓
2D PACE	Multi-breathhold

[a] TrueFISP is essentially flow-compensated from one RF pulse to the next

[b] only if Dimension = 3D is selected

Basic sequences: TrueFISP, sequence description (II)

CV (without ECG)

Sequence type	Cine	Define	Shots per slice	View sharing
Trufi	On	Shots	1	Shared phases

Fast single-shot TrueFISP sequence with phase sharing. Measurement and reconstruction of multiple images (phases) in a single cardiac cycle.

Use
For displaying dynamic processes.
To display cardiac motion without a breathhold phase.
To examine cardiac volume in a breathhold phase; multi-phase measurement of multiple sequential slices is possible.

Please note: The sequence can run without triggering for real-time monitoring of cardiac or other motions. If only the basic sequences are available, ECG/pulse triggering is not available.

CV sequence > p. 72

TE variable	–[a]
Contrasts	1
Bandwidth variable	✓
Magn. Prep.	–
Reconstruction mode	Magnitude
Fat suppression	–
Phase Partial Fourier	–
Asymm. Echo	Possible
Averaging mode	Short term
Multi-slice mode	Sequential
Flow compensation	No[b]
Dimension	2D
Elliptical scanning[c]	–
Slice resolution [c]	–
Slice Partial Fourier[c]	–
Excitation pulses[c]	–
RF pulse type	Fast/Normal
RF spoiling	Off
Gradient mode	Fast/Normal/Whisper
iPAT	✓
iPAT^2	–
Multi-breathhold	–
2D PACE	–

[a] TE is automatically set to the minimum and cannot be changed

[b] TrueFISP is essentially flow-compensated from one RF pulse to the next

[c] only if Dimension = 3D is selected

Basic sequences: TrueFISP, sequence description (III)

CV (without ECG)

Sequence type	Define	Shots per slice	Magn. preparation
Trufi	Shots	1	IR/SR/SR perf

Single-shot TrueFISP sequence.
Can be combined with inversion recovery and saturation recovery preparation pulses. Image reconstruction allows for Partial Fourier factors of 4/8 and 5/8.

Saturation Recovery (SR) or Saturation Recovery Perfusion (SR perf)?

- SR: Rectangular saturation pulse (normally 90 degrees)
- SR perf: Echo train with 3 saturation pulses (90 degrees each) as well as different time intervals and gradient spoilers. More robust with respect to magnetic field inhomogeneities, however, with a higher SAR.

Use

For sequential multi-slice applications.

Segments	Variable[b]
TE variable	–[a]
Contrasts	1
Bandwidth variable	✓
Magn. Preparation	IR, SR, selective, non-selective
Reconstruction mode	Magnitude
Fat suppression	Possible
Saturation regions	–
MTC	–
Phase Partial Fourier	✓
Asymm. Echo	✓
Averaging mode	Short term
Multi-slice mode	Sequential
Flow compensation	No[c]
Dimension	2D/3D
RF pulse type	Fast/Normal
RF spoiling	Off
Gradient mode	Fast/Normal/Whisper
Dark blood	–
Tagging	–
iPAT	✓
Multi-breathhold	–
2D PACE	–

[a] TE is automatically set to the minimum and cannot be changed

[b] max. number of segments depends on the number of lines

[c] TrueFISP is essentially flow-compensated from one RF pulse to the next

Basic sequences: TrueFISP, sequence description (IV)

CV

Sequence type	Cine
Trufi	On

Segmented TrueFISP sequence.
The sequence is triggered prospectively.
The sequence runs continuously to maintain the steady state.

Use

To display cardiac motion. Provides good contrast of blood and myocardium.

Segments	3–31
TE variable	–[a]
Contrasts	1
Bandwidth variable	✓
Magn. Preparation	–
Reconstruction mode	Magnitude
Fat suppression	–
Saturation regions	–
MTC	–
Phase Partial Fourier	✓
Asymm. Echo	–
Averaging mode	Short term
Multi-slice mode	Sequential
Flow compensation	No
Dimension	2D (only untriggered)
RF pulse type	Fast/Normal
RF spoiling	Off
Gradient mode	Fast/Normal/Whisper
Dark blood	–
Tagging	–
iPAT	✓
Multi-breathhold	✓
2D PACE	Multi-breathhold

[a] TE is automatically set to the minimum and cannot be changed

Basic sequences: TrueFISP, sequence description (V)

CV

Sequence type	Cine
Trufi	Off

Segmented TrueFISP sequence.
It can be combined with a variety of selective or non-selective preparation pulses (fat saturation, inversion recovery, saturation recovery, and dark blood).

Use

For 2D or 3D applications.
To characterize tissue and angiography.

Segments	Variable[b]
TE variable	–[a]
Contrasts	1
Bandwidth variable	✓
Magn. Preparation	IR, SR, selective, non-selective
Reconstruction mode	Magnitude
Fat suppression	✓
Saturation regions	Regular/Parallel
MTC	–
Phase Partial Fourier	✓
Asymm. Echo	✓
Averaging mode	Short term
Multi-slice mode	Sequential
Flow compensation	No[c]
Dimension	2D/3D
RF pulse type	Fast/Normal
RF spoiling	Off
Gradient mode	Fast/Normal/Whisper
Dark blood	✓
Tagging	–
iPAT	✓
Multi-breathhold	✓
2D PACE	–

[a] TE is automatically set to the minimum and cannot be changed

[b] max. number of segments depends on the number of lines

[c] TrueFISP is essentially flow-compensated from one RF pulse to the next

Basic sequences: TrueFISP, sequence description (VI)

CV

Sequence type	Cine	Magn. preparation
Trufi	On	TI Scout

TrueFISP sequence. After a single preparation pulse, several images can be acquired—either segmented or with the single-shot technique. The contrast of result images varies depending on the time duration TI following the preparation pulse.

Use
For T1 mapping and determining a suitable TI.

Segments	Variable[a]
TE variable	–
Contrasts	Variable
Bandwidth variable	✓
Magn. Preparation	TI Scout
Reconstruction mode	Magnitude
Fat suppression	–
Saturation regions	–
MTC	–
Phase Partial Fourier	–
Asymm. Echo	✓
Averaging mode	Short term
Multi-slice mode	Sequential
Flow compensation	–
Dimension	2D
RF pulse type	Fast/Normal
RF spoiling	Off
Gradient mode	Fast/Normal/Whisper
Dark blood	–
Tagging	–
iPAT	–
Multi-breathhold	–
2D PACE	–

[a] max. number of segments depends on the number of lines

Basic sequences: TrueFISP, sequence description (VII)

trufi_ freqScout

TrueFISP sequence. Several images of identical geometry, but different offset frequency are acquired. The distance of the frequency shifts and the number of images are controlled via the parameters **Trufi delta freq.** and **Measurements**. The offset frequencies are included in the image text. A visual analysis in the Viewer determines the optimal frequency. It is entered in subsequent measurements for the **Trufi delta freq.** parameter.

Use

Especially with TrueFISP protocols it may be necessary to adjust the offset frequency based on the image to move the typical TrueFISP stripe artifacts out of the region of interest.

Segments	Variable
TE variable	✓
Contrasts	1
Bandwidth variable	✓
Magn. Preparation	–
Reconstruction mode	Magnitude
Fat suppression	–
Saturation regions	–
MTC	–
Phase Partial Fourier	✓
Asymm. Echo	✓
Averaging mode	Short term/long term
Multi-slice mode	Sequential/ Single measurement
Flow compensation	–
Dimension	2D
RF pulse type	Fast/Normal/Low SAR
RF spoiling	–
Gradient mode	Fast/Normal/Whisper
Dark blood	–
Tagging	–
iPAT	✓
Multi-breathhold	–
2D PACE	–

Basic sequences: EPI sequences, sequence description

ep2d_se

Single-shot spin echo EPI sequence.

Use

To examine T2-weighted lesions.

Recommendations: By activating an inversion pulse with a long inversion time, the CSF signal in the head can be suppressed.

ep_seg_fid

Segmented FID EPI sequence. Faster than gradient echo sequences, less off resonance effects than the single-shot FID EPI sequence.

Use

T2*-weighted 2D/3D imaging in the head.

ep_seg_se	Segmented spin echo EPI sequence. Faster than spin echo sequences, less off resonance effects than a single-shot spin echo EPI sequence. **Use** Fast T2-weighted 2D/3D imaging in the head.

Basic sequences: EPI sequences, parameter ranges

	ep2d_se
EPI Factor	1–256[a]
TE variable	✓
Contrasts	1
Bandwidth variable	Min ... max
Magn. Preparation	IR
Recon. mode	Magnitude
Fat suppression	Fat saturation/ water excitation/SPAIR
Saturation regions	Regular/Parallel
MTC	✓
Phase Partial Fourier	✓
Averaging mode	Long term
Multi-slice mode	Interleaved
Flow compensation	No
Dimension	2D
RF pulse type	Normal/Low SAR
RF spoiling	Off
Gradient mode	Fast/Normal
iPAT	✓
Multi-breathhold	–
2D PACE	–

ep_seg_fid	ep_seg_se
1 – 127	1 – 127
✓	✓
1	1
Min ... max	Min ... max
–	IR
Magnitude	Magnitude
Fat saturation/ water excitation	Fat saturation/ water excitation
Regular/Parallel	Regular/Parallel
✓	✓
✓	✓
Long term	Long term
Interleaved/ sequential	Interleaved/ sequential
No	No
2D/3D	2D/3D
Normal	Normal
On/Off	Off
Fast/Normal	Fast/Normal
–	–
✓	✓
Multi-breathhold	Multi-breathhold

[a] parameter cannot be freely set, depends on base and phase resolution

CISS & DESS: Sequence description

dess

3D gradient echo sequence

Use

Primarily in orthopedic imaging with good contrast between synovial fluid and cartilage.

Recommendations: A non-selective excitation pulse is activated beforehand for fat suppression at a short TR.

ciss

3D gradient echo sequence for T2 imaging at a large flip angle. TE and TR are permanently set to a minimum value to ensure best possible image quality.

Use

Can be used in neurology, where CSF provides contrast: cochlea, labyrinth, cranial nerves, optic nerve tract, spinal canal, etc.

	dess	ciss
TE variable	✓	Min.
Contrasts	1	1
Bandwidth variable	✓	✓
Recon. mode	Magnitude	Magnitude
Fat suppression	Water excitation	Water excitation
Phase Partial Fourier	✓	✓
Averaging mode	Short term/ long term	Short term
Multi-slice mode	Sequential	Sequential
Flow compensation	Readout	No
Dimension	3D	2D/3D
Elliptical scanning[a]	✓	✓
Slice resolution[a]	✓	✓
Slice Partial Fourier[a]	✓	✓
Excitation pulses[a]	Slab-selective/ non-selective	Slab-selective
RF pulse type	Fast/Normal	Fast/Normal
RF spoiling	Off	Off
Gradient mode	Fast/Normal/ Whisper	Fast/Normal/ Whisper
iPAT	✓	–

[a] only if Dimension = 3D is selected

TGSE: Sequence description

tgse

Ultrafast turbo gradient spin echo sequence for high resolution imaging or extremely short measurement times.
At an EPI factor of 1 and a Turbo factor >1, the sequence behaves like a tse sequence.
At a Turbo factor of 1 and an EPI factor >1, the sequence behaves like a segmented EPI sequence.

Recommendations: If SAR is exceeded, either the flip angle of the refocusing pulse can be reduced and/or RF pulse type "Low SAR" can be selected. A smaller flip angle (e.g., approx. 150°) does not have a noticeable effect on image contrast.

Use

T2 weighting for high-resolution neuro or ortho imaging in an acceptable measurement time (recommended EPI factor at a high turbo factor ≤3).
Inversion recovery neuro imaging with magnitude or real value image display.

Please note: Increasing the EPI factor increases the sequence's susceptibility sensitivity; distortion artifacts may increase.

TGSE: Parameter ranges

	tgse
Turbo factor	1–65
EPI factor	1–21
TE variable	✓[b]
Contrasts	1
Bandwidth variable	✓
Magn. Preparation	IR
Reconstruction mode	Magnitude/Real[a]
Fat suppression	Fat saturation
Saturation regions	Regular/Parallel
MTC	✓
Phase Partial Fourier	–
Averaging mode	Short term/long term
Multi-slice mode	Interleaved/sequential
Flow compensation	No
Dimension	2D
RF pulse type	Fast/Normal/Low SAR
Gradient mode	Fast/Normal/Whisper
Dark blood	✓
Multi-breathhold	✓
2D PACE	Multi-breathhold

[a] may be selected only if Magn.Preparation = IR has been selected

[b] applies only, when turbo factor = 1

AutoAlign: Sequence description

AALScout

Modified fl3d_vibe sequence for AutoAlign scouts in AutoAlign programs and Dot Engines. For adjusting, measuring 3D volumes, and computing AutoAlign matrices. The algorithm uses bone markers (L = landmark-based) for automatic slice positioning.

Use

The sequence must precede any examination with AutoAlign. The slice position of subsequent measurement protocols is automatically adjusted with AutoAlign.

Please note: The sequence parameters cannot be changed. *Exception:* coil selection and iPAT factor.

Cardiac imaging: Sequence description (I)

The CV sequence combines a multitude of functions which were implemented in various cardio sequences in previous software versions. These include, e.g., functions such as retrospective triggering, radial k-space sampling, shared phases, GRE and TrueFISP contrast, 2D/3D acquisitions, magnetization preparations, Cine, TI Scout, etc..

CV

Sequence type	Cine	1st Signal/Mode
Trufi	On	ECG/Retro

Segmented TrueFISP sequence. Triggered, retrospective gating: Measurement of the k-space lines is triggered prospectively, however, the measurement data are sorted and reconstructed retrospectively. As a result, the entire cardiac cycle can be acquired.

Use

To display cardiac motion of a complete cardiac cycle. Provides good contrast of the blood and myocardium. Particularly suited for patients with arrhythmias.

Segments	Variable[b]
TE variable	–[a]
Contrasts	1
Bandwidth variable	✓
Magn. Preparation	–
Reconstruction mode	Magnitude
Fat suppression	–
Saturation regions	–
MTC	–
Phase Partial Fourier	–
Asymm. Echo	–
Averaging mode	Short term
Multi-slice mode	Sequential
Flow compensation	No
Dimension	2D
RF pulse type	Fast/Normal
RF spoiling	Off
Gradient mode	Fast/Normal/Whisper
Dark blood	–
Tagging	–
iPAT	✓
Multi-breathhold	✓
2D PACE	–

[a] TE is automatically set to the minimum and cannot be changed

[b] max. number of segments depends on the number of lines

Cardiac imaging: Sequence description (II)

CV

Sequence type	Cine	View sharing	1st Signal/ Mode
Trufi	On	Shared phases	ECG/Trigger

Similar to the previous sequence, however, with phase sharing for improved temporal resolution.

Use

To display cardiac motion. Provides good contrast of blood and myocardium.
For short breathhold studies or multiple slice measurements within one breathhold phase.

Segments	Variable[b]
TE variable	–[a]
Contrasts	1
Bandwidth variable	✓
Magn. Preparation	–
Reconstruction mode	Magnitude
Fat suppression	–
Saturation regions	–
MTC	–
Phase Partial Fourier	–
Asymm. Echo	–
Averaging mode	Short term
Multi-slice mode	Sequential
Flow compensation	No[c]
Dimension	2D
RF pulse type	Fast/Normal
RF spoiling	Off
Gradient mode	Fast/Normal/Whisper
Dark blood	–
Tagging	–
iPAT	✓
Multi-breathhold	✓
2D PACE	–

[a] TE is automatically set to the minimum and cannot be changed

[b] max. number of segments depends on the number of lines

[c] TrueFISP is essentially flow-compensated from one RF pulse to the next

Cardiac imaging: Sequence description (III)

CV

Sequence type	Cine	Trajectory
Trufi	On	Radial

Segmented TrueFISP sequence.
The sequence is triggered prospectively or retrospectively. Radial sampling of the k-space improves temporal and spatial resolution.

Use
To display cardiac motion.

Segments	Variable[b]
TE variable	–[a]
Contrasts	1
Bandwidth variable	✓
Magn. Preparation	–
Reconstruction mode	Magnitude
Fat suppression	–
Saturation regions	–
MTC	–
Phase Partial Fourier	–
Asymm. Echo	–
Averaging mode	Short term
Multi-slice mode	Sequential
Flow compensation	No
Dimension	2D
RF pulse type	Fast/Normal
RF spoiling	Off
Gradient mode	Fast/Normal/Whisper
Dark blood	–
Tagging	–
iPAT	–
Multi-breathhold	✓
2D PACE	–

[a] TE is automatically set to the minimum and cannot be changed

[b] max. number of segments depends on the number of lines

Cardiac imaging: Sequence description (IV)

CV

Sequence type	Cine	1st Signal/Mode
Gre	On	ECG/Retro

Segmented FLASH sequence. Triggered retrospective gating possible.

Use

To display cardiac motion. Especially well suited for the display of cardiac valve diseases. In particular for patients with arrhythmias.

Segments	–
TE variable	✓
Contrasts	1
Bandwidth variable	✓
Magn. Preparation	–
Reconstruction mode	Magnitude
Fat suppression	–
Saturation regions	Regular/Parallel
MTC	–
Phase Partial Fourier	–
Asymm. Echo	✓
Averaging mode	Short term
Multi-slice mode	Sequential
Flow compensation	Yes/No/Slice&Readout
Dimension	2D
RF pulse type	Fast/Normal
RF spoiling	On
Gradient mode	Fast/Normal/Whisper
Dark blood	–
Tagging	✓
iPAT	✓
Multi-breathhold	✓
2D PACE	–

Cardiac imaging: Sequence description (V)

CV

Sequence type	Cine	1st Signal/ Mode	View sharing
Gre	On	ECG/Trigger	Shared phases

2D shared phase gradient echo sequence.

Use

To display cardiac motion.

Segments	Variable[a]
TE variable	✓
Contrasts	1
Bandwidth variable	✓
Magn. Preparation	–
Reconstruction mode	Magnitude
Fat suppression	Fat saturation
Saturation regions	Regular/Parallel
MTC	✓
Phase Partial Fourier	✓
Asymm. Echo	✓
Averaging mode	Short term/long term
Multi-slice mode	Sequential
Flow compensation	Yes/No/Slice&Readout
Dimension	2D
RF pulse type	Fast/Normal
RF spoiling	On/off
Gradient mode	Fast/Normal/Whisper
Dark blood	–
Tagging	✓
iPAT	–
Multi-breathhold	✓
2D PACE	Multi-breathhold

[a] max. number of segments depends on the number of lines

Cardiac imaging: Sequence description (VI)

CV (with ECG)

Sequence type	Cine	Define	Shots per slice	View sharing	1st Signal/ Mode
Trufi	On	Shots	1	Shared phases	ECG/ Trigger

Fast single-shot TrueFISP sequence with phase sharing. Measurement and reconstruction of multiple images (phases) in a single cardiac cycle.

Use

To display cardiac motion without a breathhold phase. To examine cardiac volume in a breathhold phase; multi-phase measurement of multiple sequential slices is possible.

Please note: The sequence can be run without triggering for real-time monitoring of cardiac or other motions.

Segments	–
TE variable	–[a]
Contrasts	1
Bandwidth variable	✓
Magn. Preparation	–
Reconstruction mode	Magnitude
Fat suppression	–
Saturation regions	–
MTC	–
Phase Partial Fourier	–
Asymm. Echo	–
Averaging mode	Short term
Multi-slice mode	Sequential
Flow compensation	No[b]
Dimension	2D
RF pulse type	Fast/Normal
RF spoiling	Off
Gradient mode	Fast/Normal/Whisper
Dark blood	–
Tagging	–
iPAT	✓
Multi-breathhold	–
2D PACE	–

[a] TE is automatically set to the minimum and cannot be changed

[b] TrueFISP is essentially flow-compensated from one RF pulse to the next

Cardiac imaging: Sequence description (VII)

CV

Sequence type	Cine	Trajectory	Define	Shots per slice
Trufi	On	Radial	Shots	1

Real-time TrueFISP sequence to measure multiple images in a cardiac cycle; with or without ECG synchronization. Radial sampling of the k-space improves temporal and spatial resolution.

Use
To display cardiac motion in real time.

Segments	–
TE variable	–[a]
Contrasts	1
Bandwidth variable	✓
Magn. Preparation	–
Reconstruction mode	Magnitude
Fat suppression	–
Saturation regions	–
MTC	–
Phase Partial Fourier	–
Asymm. Echo	–
Averaging mode	Short term
Multi-slice mode	Sequential
Flow compensation	No
Dimension	2D
RF pulse type	Fast/Normal
RF spoiling	Off
Gradient mode	Fast/Normal/Whisper
Dark blood	–
Tagging	–
iPAT	–
Multi-breathhold	✓
2D PACE	–

[a] TE is automatically set to the minimum and cannot be changed

Cardiac imaging: Sequence description (VIII)

CV_nav

Combination of CV sequence (sequence type **Trufi**, Cine **Off**) and the prospective measurement of a navigator echo.

Use

To display the coronary arteries with free breathing.

To display the renal arteries in NATIVE True-FISP protocols.[a]

tse_nav

2D TurboSE with dark blood preparation and the prospective measurement of a navigator echo.

Use

To display the morphology of the heart and coronary arteries with free breathing.

[a] *with NATIVE licencse*

	CV_nav	tse_nav
Segments	Variable[b]	–
TE variable	–[a]	✓
Contrasts	1	1
Bandwidth variable	✓	✓
Magn. Preparation	IR, SR, selective, non-selective	–
Recon. mode	Magnitude	Magnitude
Fat suppression	✓	✓
Saturation regions	Regular/Parallel	Regular/Parallel
Inversion regions[d]	up to 4 (with different TI)	–
Phase Partial Fourier	✓	–
Asymm. Echo	✓	–
Averaging mode	Short term	Short term
Multi-slice mode	Sequential	Interleaved
Flow compensation	No[c]	No
Dimension	2D/3D	2D/3D
RF pulse type	Fast/Normal	Fast/Normal
RF spoiling	Off	Off
Gradient mode	Fast/Normal/ Whisper	Fast/Normal/ Whisper
Dark blood	✓	✓
iPAT	✓	–

[a] TE is automatically set to the minimum and cannot be changed

[b] max. number of segments depends on the number of lines

[c] TrueFISP is essentially flow-compensated from one RF pulse to the next

[d] with NATIVE license

Cardiac imaging: Sequence description (IX)

CV

Sequence type	Cine	Flip angle mode
Gre	Off	Variable

2D gradient echo sequence with a variable flip angle.

Use
Display of individual slices within a breath-hold phase.

Recommendations: To increase signal intensity, each line is measured at a different flip angle. Since the magnetization is saturated, it is necessary to wait for the next cardiac cycle to allow for recovery of the magnetization. Therefore, only one cardiac phase can be measured.

Segments	1–23
TE variable	✓
Contrasts	1
Bandwidth variable	✓
Magn. Preparation	–
Reconstruction mode	Magnitude
Fat suppression	Fat saturation
Saturation regions	Regular/Parallel
MTC	✓
Phase Partial Fourier	✓
Asymm. Echo	✓
Averaging mode	Short term/long term
Multi-slice mode	Sequential
Flow compensation	Yes
Dimension	2D
RF pulse type	Fast/Normal
RF spoiling	On/off
Gradient mode	Fast/Normal/Whisper
Dark blood	–
Tagging	✓
iPAT	–
Multi-breathhold	✓
2D PACE	Multi-breathhold

Cardiac imaging: Sequence description (X)

CV (with ECG), CV epi

Sequence type	Define	Shots per slice	Magn. preparation	1st Signal/Mode
Trufi Gre Gre epi	Shots	1	IR/SR/SR perf	ECG/Trigger

Single-shot sequences. Can be combined with inversion recovery or saturation recovery preparation pulses. Image reconstruction allows for Partial Fourier factors of 6/8 and 7/8 (Trufi and Gre).

Saturation Recovery (SR) or Saturation Recovery Perfusion (SR perf)?

- SR: Rectangular saturation pulse (normally 90 degrees)
- SR perf: Echo train with 3 saturation pulses (90 degrees each) as well as different time intervals and gradient spoilers. More robust with respect to magnetic field inhomogeneities, however, with a higher SAR.

Use

For sequential multi-slice applications.

Segments	Fixed[b]
TE variable	–[a]
Contrasts	1
Bandwidth variable	✓
Magn. Preparation	IR, SR, selective, non-selective
Reconstruction mode	Magnitude
Fat suppression	Yes (Gre epi)
Saturation regions	–
MTC	–
Phase Partial Fourier	–
Asymm. Echo	✓
Averaging mode	Long term
Multi-slice mode	Single-shot
Flow compensation	No[c] (Gre)
Dimension	2D/3D
RF pulse type	Fast/Normal
RF spoiling	On (Gre and Gre epi)
Gradient mode	Fast/Normal/Whisper
PAT	Integrated/tPAT

[a] TE is automatically set to the minimum and cannot be changed

[b] max. number of segments depends on the number of lines

[c] TrueFISP is essentially flow-compensated from one RF pulse to the next

Cardiac imaging: Sequence description (XI)

CV (with ECG)

Sequence type	Magn. preparation	1st Signal/ Mode	Recon-struction
Trufi Gre	IR	ECG/Trigger	Magnitude/ Real

TrueFISP and TurboFLASH sequences (segmented and single-shot) to create phase-sensitive inversion recovery images (real part and magnitude images).
The contrast in real part images is less dependent on the optimal selection of the inversion time. Image reconstruction allows for Partial Fourier factors of 6/8 and 7/8 (Trufi and Gre).

Segments	Variable and fixed[b]
TE variable	–[a]
Contrasts	1
Bandwidth variable	✓
Magn. Preparation	IR, selective, non-selective
Reconstruction mode	Magnitude/Real
Fat suppression	–
Saturation regions	–
MTC	–
Phase Partial Fourier	–
Asymm. Echo	✓
Averaging mode	Short term
Multi-slice mode	Sequential
Flow compensation	No[c] (Gre)
Dimension	2D
RF pulse type	Fast/Normal
RF spoiling	On (Gre)
Gradient mode	Fast/Normal/Whisper
PAT	Integrated

[a] TE is automatically set to the minimum and cannot be changed

[b] max. number of segments depends on the number of lines (variable = segmented, fixed = single-shot)

[c] TrueFISP is essentially flow-compensated from one RF pulse to the next

Angiography: Contrast-enhanced angiography, sequence description

tfl_cb

2D single-shot TurboFLASH sequence.

Use

Optimized for determining arrival of bolus as preparation for contrast-enhanced angiography.

fl3d_ce

Gradient echo sequence

Use

Optimized for CE angiography.
Angiography of the carotid arteries.
Angiography of the thoracic arteries.
Angiography of the pulmonary arteries.
Basis for Care Bolus and Test Bolus protocols for determining arrival of contrast agent.
Table stepping angiography.

Recommendations: For suppressing background signal, select fat suppression (fat saturation or water excitation).

Recommendations: For Care examinations, select "3D centr. reordering" on the Angio parameter card.

Recommendations: Set inversion time TI so that the signal from the healthy myocardium is at a minimum.

Use

Examination of arteries with a triggered segmented 3D FLASH sequence with fat suppression.

Recommendations: An IR pulse can be used instead of the fat suppression pulse. In this case, set the inversion time to suppress fat.

fl3d_vibe

Gradient echo sequence

Use

For contrast-enhanced examinations of the upper abdomen.

Recommendations: For suppressing background signal, select fat suppression (fat saturation or water excitation).

Angiography: Contrast-enhanced angiography, parameter ranges (I)

	tfl_cb
Segments	–
TE variable	Min.
Contrasts	1
Bandwidth variable	✓
Magn. Prep.	IR/SR
Recon. mode	Magnitude/Real[c]
Fat suppression	Water excitation
Saturation regions	–
MTC	–
Phase Partial Fourier	✓
Asymm. Echo	Off/allowed
Averaging mode	Long term
Multi-slice mode	Single-shot
Flow compensation	No

	tfl_cb
Dimension	2D
Elliptical scanning[d]	–
Slice resolution[d]	–
Slice Partial Fourier[d]	–
Excitation pulse	Slice-selective
RF pulse type	Fast/Normal
RF spoiling	On
Gradient mode	Fast/Normal
Dark blood	✓
CARE Bolus	–
iPAT	–
iPAT^2	–
Multi-breathhold	–
2D PACE	–

[a] if segments >1 (segmented TurboFLASH)

[b] Partial Fourier is selected. However, the setting cannot be changed

[c] may be selected only if Magn. Preparation = IR or SR has been selected

[d] only if Dimension = 3D is selected

Angiography: Contrast-enhanced angiography, parameter ranges (II)

	fl3d_ce	**fl3d_vibe**
Segments	1–127	–
TE variable	✓[d]	✓[c]
Contrasts	1	1–2
Bandwidth variable	✓	✓
Magn. Prep.	IR[a]	–
Recon. mode	Magnitude	Magnitude
Fat suppression	Fat saturation/ water excitation	Fat saturation/ water excitation/ SPAIR
Dixon	–	✓
Saturation regions	Regular/Parallel	Regular/Parallel
MTC	–	–
Phase Partial Fourier	✓	✓
Asymm. Echo	Allowed	Off/Weak/Strong
Averaging mode	Short term	Short term
Multi-slice mode	Interleaved/ sequential	Interleaved/ sequential
Flow compensation	No	No
Dimension	2D/3D	3D
Elliptical scanning[b]	✓[f]	✓
Slice resolution[b]	✓	✓
Slice Partial Fourier[b]	✓	✓
Excitation pulse	Slab-selective/ non-selective	Slab-selective
RF pulse type	Fast/Normal/ Low SAR	Fast/Normal

	fl3d_ce	fl3d_vibe
RF spoiling	On	On
Phase enc. rewinder	✓	–
Gradient mode	Fast/Normal/ Whisper	Fast/Normal/ Whisper
Dark blood	–	–
3D centric reordering	✓	✓
Time to center[e]	✓	–
iPAT	✓	✓
iPAT^2	✓	✓
CAIPIRINHA[g]	–	✓
Multi-breathhold	–	✓
2D PACE	–	Multi-breathhold
Readout mode	–	Monopolar/Bipolar
Liver registration	–	✓
MapIt	–	✓

[a] if segments >1 (segmented TurboFLASH)

[b] only if Dimension = 3D is selected

[c] sequence allows a freely-selectable TE, an automatic minimal TE, or an automatic TE set to the "in-phase" or "opposed-phase" time

[d] sequence allows a freely-selectable TE, an automatic minimal TE, or an automatic minimal TE and TR

[e] freely selectable if 3D centric reordering is activated

[f] not available if iPAT is activated

[g] CAIPIRINHA is a generalization of iPAT^2 allowing undersampling on a sheared grid. (For a detailed description, please refer to "Supplement - Parameters and Image text".)

Angiography: Rephased-dephased angiography, sequence description

fl3d_rd

Magnitude contrast gradient echo sequence.

Use

To display the arteries of the leg with a 3D measurement.

	fl3d_rd
TE variable	✓
Contrasts	1
Bandwidth variable	✓
Reconstruction mode	Magnitude
Fat suppression	Fat saturation
Saturation regions	Regular/Parallel
MTC	✓
Phase Partial Fourier	✓
Averaging mode	Short term/long term
Multi-slice mode	Sequential
Flow compensation	Yes
Dimension	3-D
Elliptical scanning	✓
Slice resolution	✓
Slice Partial Fourier	✓
Excitation pulse	Slab-selective
RF pulse type	Normal
RF spoiling	On
Gradient mode	Fast/Normal/Whisper

Angiography: Inflow angiography (ToF), sequence description

fl_tof

FLASH sequence.

Use

Inflow angiography with 2D or 3D acquisition.

3D display of intracranial vessels in sequential slice acquisition.

Display of the coronary arteries using 3D technique in sequential slice acquisition.

Application for 2D Time-of-Flight examinations.

Recommendations: For 3 dimensional applications, select the TONE pulse (depending on flow velocity) to counteract the saturation effect of blood flowing through the slab.

fl_peri_tof

2D FLASH sequence.

Use

Peripheral angiography.

ECG-triggered measurement of vessels in the legs at a high heart rate or in the kidneys, arms, and carotid arteries.

Recommendations: Perform data acquisition during the systole to obtain the maximum signal and avoid pulsation artifacts.

Angiography: Inflow angiography (ToF), parameter ranges

	fl_tof
TE variable	✓
Contrasts	1
Bandwidth variable	✓
Recon. mode	Magnitude
Saturation regions	Regular/Parallel/Tracking
MTC	✓
Phase Partial Fourier	✓
Asymm. Echo	Allowed
Averaging mode	Short term/long term
Multi-slice mode	Sequential
Flow compensation	Yes
Dimension	2D/3D
Elliptical scanning[a]	✓
Slice resolution[a]	✓
Slice Partial Fourier[a]	✓
Excitation pulse	Slab-selective
RF pulse type	Normal[b]
RF spoiling	On
Gradient mode	Fast/Normal/Whisper
iPAT	✓

[a] only if Dimension = 3D is selected

[b] if Dimension = 3D is selected TONE pulses are used, which can be optimized for different flow velocities via the TONE ramp parameter

	fl_peri_tof
Segments	1 – 23
TE variable	✓
Contrasts	1
Bandwidth variable	✓
Reconstruction mode	Magnitude
Fat suppression	–
Saturation regions	Regular/Parallel/Tracking
MTC	✓
Phase Partial Fourier	✓
Asymm. Echo	Off/allowed
Averaging mode	Short term/long term
Multi-slice mode	Sequential
Flow compensation	Yes
Dimension	2D
Excitation pulse	Slab-selective
RF pulse type	Fast/Normal
RF spoiling	On
Gradient mode	Fast/Normal/Whisper

Angiography: Phase-contrast angiography, sequence description

fl_pc

FLASH sequence. Possible online reconstructions: magnitude image, phase image, magnitude sum image.

Use 2D

Peripheral angiography, e.g., for acquiring large fluctuations in flow velocity (Multi-venc application). Also as a localizer for 3D phase contrast measurements.

Use 3D

Neuro applications, e.g., to display arterial vessel systems.

You can set the following established applications on the "Angio" parameter card:

- Multi-venc applications:
  variable velocity encoding in one spatial direction
- Single-venc applications:
  Same velocity encoding in 3 spatial directions
- Mixed venc applications:
  free selection of direction and velocity for 3 encodings

	fl_pc
Segments	1 – 25
TE variable	✓
Contrasts	1
Bandwidth variable	✓
Reconstruction mode	Magnitude
Saturation regions	Regular/Parallel/Tracking
MTC	✓
Phase Partial Fourier	–
Asymm. Echo	✓
Averaging mode	Off/Weak/Strong
Multi-slice mode	Sequential
Flow compensation	Yes
Dimension	2D/3D
Elliptical scanning[a]	✓
Slice resolution[a]	✓
Slice Partial Fourier[a]	–
Excitation pulse	Slab-selective
RF pulse type	Fast/Normal
RF spoiling	On
Gradient mode	Fast/Normal/Whisper
Venc cm/s	1 – 999

[a] only if Dimension = 3D is selected

TimCT Angiography: Sequence description

The TimCT angiography enables examinations of large body areas with continuous table move. The otherwise necessary measurement pauses, where the patient table is moved from one stage to the next, are no longer necessary. The result is a uniform image quality in the direction of the table move.

Please note: The table movement renders some conventional settings unsuitable, e.g., tilting of the slice block from the movement axis of the table or several averages.

fl3d_ce_ct

Gradient echo sequence.

Use

Optimized for CE angiography of the peripheral vessels with continuous table move.

	fl3d_ce_ct
Segments	1
TE variable	Min.
Contrasts	1
Bandwidth variable	✓
Magn. Preparation	–
Reconstruction mode	Magnitude
Fat suppression	–
Saturation regions	–
MTC	–
Phase Partial Fourier	✓
Asymm. Echo	Allowed
Flow compensation	No
Dimension	3D
Elliptical scanning	✓
Slice resolution	✓
Slice Partial Fourier	✓
Excitation pulse	Slab-selective
RF pulse type	Fast/Normal/Low SAR
RF spoiling	On
Gradient mode	Fast/Normal
3D centric reordering	–
iPAT	✓
$iPAT^2$	–
Variable resolution	✓

Angiography: Fast dynamic imaging, sequence description

TWIST

Gradient echo sequence. Faster sequences of 3D image data than with a standard gradient echo sequence.

Use

To evaluate dynamic processes with high spatial and temporal resolution.

Recommendations: In the **Angio/Common** parameter card: The parameter **Central region A** provides the size of the central k-space and the parameter **Sampling density B** indicates the sampling density in the peripheral region. To increase temporal resolution, either reduce parameter A or B.

TE variable	Min.
Contrasts	1
Bandwidth variable	✓
Reconstruction mode	Magnitude
MTC	–
Phase Partial Fourier	✓
Asymm. Echo	Off/Weak/Strong
Averaging mode	Short term
Multi-slice mode	Interleaved/sequential
Flow compensation	No
Dimension	3D
Elliptical scanning[a]	✓
Slice resolution	✓
Slice Partial Fourier	✓
Excitation pulses	Slab-selective/ non-selective
RF pulse type	Fast/Normal/Low SAR
RF spoiling	On
Gradient mode	Fast/Normal/Whisper
iPAT	✓
iPAT^2	✓
Central region A	4–100%
Sampling density B	0–50%
Temporal interpolation	✓
Time stamp in image	✓

[a] not available if iPAT is activated

Flow quantification: Sequence description

fl_fq

Segmented FLASH sequence with variable flow encoding. The sequence measures one flow-compensated and one flow-encoded measurement. Possible online reconstructions: Magnitude image, phase image, magnitude sum image

Use

To display and quantify blood flow. Through-plane measurements for flow quantification and in-plane measurements for flow display.

fl_fq_shphs

Segmented FLASH sequence with phase sharing and variable flow encoding. The sequence measures a flow-compensated and a flow-encoded scan. Phase sharing enables more frequent sampling of the center raw data lines during pulsating flow.

Use

To display and quantify blood flow. Through-plane measurements for flow quantification and in-plane measurements for flow display. Enables flow measurement in breathhold technique using phase sharing.

	fl_fq	fl_fq_shphs
Segments	1–25	3–7
TE variable	✓	✓
Contrasts	1	1
Bandwidth variable	✓	✓
Recon. mode	Magnitude	Magnitude
Saturation regions	Regular/Parallel/ Tracking	Regular/Parallel
MTC	✓	–
Phase Partial Fourier	–	–
Asymm. Echo	✓	3 (fixed)
Averaging mode	Short term/long term	–
Multi-slice mode	Sequential	Sequential
Flow compensation	Yes	Yes
Dimension	2D	2D
Excitation pulse	Slice-selective	Slice-selective
RF pulse type	Fast/Normal	Fast/Normal
RF spoiling	On	On
Gradient mode	Fast/Normal/ Whisper	Fast/Normal/ Whisper
Venc cm/s	2–999	2–999
Multi-breathhold	–	–

[a] TE is automatically set to the minimum and cannot be changed

[b] max. number of segments depends on the number of lines

Flow quantification and phase-contrast angiography: Sequence description

BEAT_FQ

CV based flow sequence.

Use flow quantification

- To display and quantify blood flow. Through-plane measurements for flow quantification and in-plane measurements for flow display.
- Triggered, retrospective gating possible, to display and quantify blood flow during complete heart cycle coverage. Particularly suited for patients with arrhythmias.
- Enables flow measurement in breathhold technique using phase sharing. Phase sharing enables more frequent sampling of the center raw data lines during pulsating flow.

Use phase-contrast angiography

- Peripheral angiography, e.g., for acquiring large fluctuations in flow velocity (Multi-venc application)
- Localizer for 3D phase contrast measurements
- Neuro applications, e.g., to display arterial vessel systems.

You can set the following established applications on the “Angio” parameter card:

- Multi-venc applications:
  variable velocity encoding in one spatial direction
- Single-venc applications:
  Same velocity encoding in 3 spatial directions
- Mixed venc applications:
  free selection of direction and velocity for 3 encodings

Flow quantification and phase-contrast angiography: Parameter ranges

	BEAT_FQ
Segments	Variable
TE variable	✓
Contrasts	1
Bandwidth variable	✓
Reconstruction mode	Magnitude
Asymm. Echo	✓
Averaging mode	Short term/long term
Multi-slice mode	Sequential
Flow compensation	Yes
Dimension	2D/3D
Elliptical scanning[a]	✓
Slice resolution[a]	✓
Excitation pulse	Slab-selective
RF pulse type	Fast/Normal
RF spoiling	On
Gradient mode	Fast/Normal/Whisper
Venc cm/s	1 – 999

[a] only if Dimension = 3D is selected

Diffusion imaging: Sequence description

	The basic functionality is already included in the basic sequences.
ep2d_diff	Single-shot spin echo EPI sequence. **Use** For diffusion imaging. **Recommendations:** To minimize image distortions through susceptibility, select a bandwidth that enables use of minimum echo spacing. **Note:** Diffusion-specific parameters are selected from the Diff parameter card: Direction(s) of the diffusion-sensitive axis(es) (diffusion mode), number and magnitude of b-values, reconstruction mode (ADC image, Trace images).

resolve

Multi-shot, diffusion-weighted, readout-segmented EPI sequence.
During diffusion preparation, multi-shot DWI is sensitive to brain motion caused by CSF pulsation. This leads to non-linear phase errors that vary from shot to shot. The effect of these phase errors can be minimized by using a readout-segmented EPI readout in conjunction with 2D navigator phase correction and navigator-based reacquisition.

Use

For improved image quality in neuro imaging compared to standard single-shot EPI sequence.

Recommendations: For a given spatial resolution, reduce the minimum echo spacing (and the associated artifacts) by increasing the number of "Readout segments". For a fixed echo spacing, increase the available spatial resolution by increasing the number of "Readout segments".

Diffusion imaging: Parameter ranges

	ep2d_diff	resolve
EPI Factor[a]	1 – 256	1 – 256
TE variable	✓	–[b]
Contrasts	1	2
Bandwidth variable	Min ... max	–[b]
Magn. Preparation	IR	IR
Recon. mode	Magnitude	Magnitude
Fat suppression	Fat saturation/ water excitation/ SPAIR	Fat saturation/ water excitation/ SPAIR
Saturation regions	Regular/Parallel	Regular/Parallel
MTC	✓	✓
Phase Partial Fourier	✓	–
Averaging mode	Long term	Long term
Multi-slice mode	Interleaved	Interleaved
Flow compensation	No	No
Dimension	2D	2D
RF pulse type	Normal/Low SAR	Normal/Low SAR
RF spoiling	Off	Off

	ep2d_diff	resolve
Gradient mode	Fast/Normal	Fast
b-value	0–10000	0–10000
Online reconstruction	DW and ADC image, FA image, TRACE, colored FA image	DW and ADC image, FA image, TRACE, colored FA image
iPAT	✓	✓
Multi-breathhold	✓	–
2D PACE	Multi-breathhold/ Trigger	–
Readout segments	–	✓
Reacquisition mode[c]	–	On/off
Echo spacing variable	✓	✓
Optimization	Min TE	Min TE/Min TR

[a] parameter cannot be freely set, depends on base and phase resolution

[b] parameter cannot be freely set, depends on other parameters

[c] automatically set to “off” when physiological triggering is active

Perfusion imaging: Sequence description

The basic functionality is already included in the basic sequences.

ep2d_fid

Single-shot FID EPI sequence.

Use

For perfusion imaging in the head.

You can activate online reconstruction of the following images on the Perf parameter card:

- Time to Peak (TTP)
- Global Bolus Plot (GBP)
- Percentage of Baseline at Peak (PBP)
- relative Cerebral Blood Volume (relCBV)
- relative Cerebral Blood Flow (relCBF)
- relative Mean Transit Time (relMTT)

Recommendations: To minimize image distortions through susceptibility, select a bandwidth that enables use of minimum echo spacing.

ep2d_pasl

Single-shot FID EPI sequence.

Use

For perfusion imaging in the head. As a result, you obtain perfusion-weighted images and relCBF images.

tgse_pasl

Segmented turbo gradient spin echo sequence for high resolution imaging or extremely short measurement times.
At an EPI factor of 1 and a Turbo factor >1, the sequence behaves like a tse sequence.
At a Turbo factor of 1 and an EPI factor >1, the sequence behaves like a segmented EPI sequence.

Use

For perfusion imaging in the head. As a result, you obtain perfusion-weighted images.

Recommendations: To minimize image distortions through susceptibility, select a bandwidth that enables use of minimum echo spacing.

Please note: Increasing the EPI factor increases the sequence's susceptibility sensitivity; distortion artifacts may increase.

Perfusion imaging: Parameter ranges

	ep2d_fid	ep2d_pasl
EPI Factor[a]	1 – 256	1 – 128
TE variable	✓	✓
Contrasts	1	1
Bandwidth variable	Min ... max	Min ... max
Magn. Preparation	–	PASL
Recon. mode	Magnitude	Magnitude
Fat suppression	Fat saturation	Fat saturation (strong/weak)
Saturation regions	Regular/Parallel	PICORE Q2T[c]
MTC	✓	–
Phase Partial Fourier	✓	✓
Averaging mode	Long term	Long term
Multi-slice mode	Interleaved	Interleaved
Flow compensation	No	No
Dimension	2D	2D
RF pulse type	Normal	Normal
RF spoiling	Off	Off
Gradient mode	Fast/Normal	Fast
Online recon-struction	TTP, GBP, PBP, relCBV, relCBF, relMTT	Perfusion-weighted images, relCBF
Flow limit	–	0 – 100 cm/s
Bolus duration	–	Variable[d]
iPAT	✓	✓
Quality check	–	On/Off/ On - extended

	tgse_pasl
Turbo factor	1 – 65
EPI factor	1 – 127
TE variable	–[b]
Bandwidth variable	✓
Magn. Preparation	PASL
Reconstruction mode	Magnitude
Fat suppression	Fat saturation
Saturation regions	FAIR QII[c]
MTC	–
Phase Partial Fourier	–
Averaging mode	Long term
Multi-slice mode	–
Flow compensation	No
Dimension	3D
RF pulse type	Normal
Gradient mode	Fast/Normal
Online reconstruction	Perfusion-weighted images
Bolus duration[e]	Variable
Inversion array size[f]	Min. 1

[a] parameter cannot be freely set, depends on base and phase resolution

[b] TE is automatically set to the minimum and cannot be changed

[c] parameter "Perfusion mode"

[d] parameter depends on TR

[e] parameter depends on TI and inversion array size

[f] maximum depends on TR and TI

BOLD imaging: Sequence description

	The basic functionality is already included in the basic sequences (ep2d_fid).
ep2d_bold	Single-shot FID EPI sequence. **Use** For BOLD imaging in the head. t-test evaluation in real time during the measurement. The calculated t-test images are shown continuously in the Inline Display.
ep2d_pace	Identical to ep2d_bold, but with prospective 3D motion correction. **Note:** By switching off motion correction, the entire function including prospective correction is deactivated.

gre_field_mapping

2D gradient echo sequence that generates images at two different echo times. The first TE is variable, the second TE is fixed relative to the first TE. The different echo times correspond to the in-phase conditions of fat and water protons.

Use

When phase images are selected, you obtain a single phase differential image that can be used as a "Fieldmap" during BOLD post-processing. The information is required when overlaying anatomical images generated with other techniques, e.g., SE or MPRAGE.

Prerequisites for using the BOLD post-processing card:

- The phase range of –PI to +PI corresponds to image pixel values of 0 to +4095
- Image geometry and slice orientation have to be identical to the EPI images
- The sequence has to be applied prior to the corresponding EPI measurement

Note: These limitations do not apply when using the 3D Neuro card.

BOLD imaging: Parameter ranges

	ep2d_bold
EPI Factor[a]	1 – 128
TE variable	✓
Contrasts	1
Bandwidth variable	Min…max
Magn. Preparation	–
Reconstruction mode	Magnitude
Fat suppression	Fat saturation/ water excitation
Saturation regions	Regular/Parallel
MTC	✓
Phase Partial Fourier	✓
Asymm. Echo	–
Averaging mode	Long term
Multi-slice mode	Interleaved
Flow compensation	No
Dimension	2D
RF pulse type	Normal
RF spoiling	Off
Gradient mode	Fast/Normal
iPAT	✓

[a] parameter cannot be freely set, depends on base and phase resolution

ep2d_pace	gre_field_mapping
1 – 128	–
✓	✓
1	2
Min...max	✓
–	–
Magnitude	Magnitude/Phase
Fat saturation/ water excitation	Fat saturation
Regular/Parallel	Regular/Parallel/Tracking
✓	✓
✓	✓
–	✓
Long term	Short term/long term
Interleaved	Interleaved/sequential
No	Yes
2D	2D
Normal	Fast/Normal
Off	On/off
Fast/Normal	Fast/Normal/Whisper
✓	–

Interactive real-time imaging: Sequence description

The BEAT_IRT sequence is optimized for interactive real-time imaging.
During the measurement, all slice parameters can be changed via graphic slice positioning and the parameter cards.
(*Prerequisite:* Sequence is started via the **Stop/Continue** in the **Inline Display**).
The slice positions can be saved during imaging and subsequently transferred to a protocol in the wait queue.
BEAT_IRT is based on the CV sequence and inherits most of the parameter settings from it.

CV sequence > p. 72

Sequence type Trufi	Fast sequence with a high signal-to-noise ratio. **Use** This sequence is very well suited for cardiac and abdominal applications.
Sequence type Gre	Slower sequence with a lower SAR than Trufi. **Use** This sequence is very well suited for interventional imaging; susceptibility effects enable a good view of biopsy needles.

Interactive real-time imaging: Parameter ranges

Sequence type	Trufi
TE variable	–[a]
Contrasts	1
Bandwidth variable	✓
Magn. Preparation	✓
Recon. mode	Magnitude
Fat suppression	–
Saturation regions	Regular
MTC	–
Phase Partial Fourier	✓
Averaging mode	Short term
Multi-slice mode	Sequential
Flow compensation	No
Dimension	2D
RF pulse type	Fast/Normal/Low SAR
RF spoiling	Off
Gradient mode	Fast/Normal/Whisper
Dark blood	✓
Trajectory	Cartesian
Slices	1

[a] TE is automatically set to the minimum and cannot be changed

Sequence type	Gre
TE variable	✓
Contrasts	1
Bandwidth variable	✓
Magn. Preparation	✓
Recon. mode	Magnitude
Fat suppression	Fat saturation/ water excitation
Saturation regions	Regular
MTC	–
Phase Partial Fourier	✓
Averaging mode	Short term
Multi-slice mode	Sequential
Flow compensation	Yes/no
Dimension	2D
RF pulse type	Fast/Normal/Low SAR
RF spoiling	On/Off
Gradient mode	Fast/Normal/Whisper
Dark blood	✓
Trajectory	Radial
Slices	1

Spectroscopy: Sequence description

The spectroscopy sequences are used to measure metabolites in different organs. Single voxel spectroscopy (svs) sequences measure a single volume within one measurement.
With chemical shift imaging (csi) multiple voxels within a volume of interest can be measured.
The fid sequence has no localization built into the sequence and localizes only by the sensitive volume of the coil.

Available sequences

- svs_se
- svs_st
- csi_se
- csi_st
- csi_slaser[a]
- fid
- csi_fid[b]

Recommendations: Use multiples of max. phase cycles.

[a] only available at systems with a field strength of 3 T
[b] only available with Multinuclear license

Sequence types

Spin echo (_se)

- Localization with three orthogonal slices
- 90°–180°–180°
- Measured signal: full spin echo

STEAM (_st)

- Localization with three orthogonal slices
- 90°–90°–90°
- Measured signal: stimulated echo
- Short TEs possible
- Only half of the spin echo signal

Semi-LASER (_slaser)

- Localization with three orthogonal slices
- 90°–180°–180°–180°–180°
- 180° pulses are adiabatic full passage pulses and used in pairs
- Measured signal: full spin echo

Spectroscopy: Parameter ranges (I)

	svs_se	svs_st
TE variable	✓	✓
Mixing time (TM) variable	–	✓
Bandwidth variable	✓	✓
Spectral fat suppression	✓	–
Saturation regions	Regular	–
Averaging mode	–	–
Dimension	–	2D
Phase cycling	✓	✓
Triggering	ECG/respiratory	–
2D PACE	✓	–
k-space weighting	–	–
Excitation of VOI	✓	✓
Multiple measurements	✓	✓
AutoAlign	✓	✓
Fully excited VOI	–	–
Water reference scan	✓	✓
Multinuclear support	–	–

	csi_se	csi_st
TE variable	✓	✓
Mixing time (TM) variable	–	✓
Bandwidth variable	✓	✓
Spectral fat suppression	✓	–
Saturation regions	Regular	–
Averaging mode	Short term/ long term	Short term/ long term
Dimension	2D/3D	2D/3D
Phase cycling	–	–
Triggering	–	–
2D PACE	–	–
k-space weighting	Full/elliptical/ weighted	Full/elliptical/ weighted
Excitation of VOI	✓	✓
Multiple measurements	✓	✓
AutoAlign	✓	✓
Fully excited VOI	✓	–
Water reference scan	–	–
Multinuclear support	–	–

Spectroscopy: Parameter ranges (II)

	csi_slaser[a]	fid
TE variable	✓	–[b]
Mixing time (TM) variable	–	–
Bandwidth variable	✓	✓
Spectral fat suppression	–	–
Saturation regions	Regular	–
Averaging mode	Short term/ long term	–
Dimension	2D/3D	–
Phase cycling	–	✓
Triggering	–	ECG/respiratory
2D PACE	–	–
k-space weighting	Full/elliptical/ weighted	–
Excitation of VOI	✓	–
Multiple measurements	✓	✓
AutoAlign	✓	–
Fully excited VOI	–	–
Water reference scan	–	–
Multinuclear support	–	✓

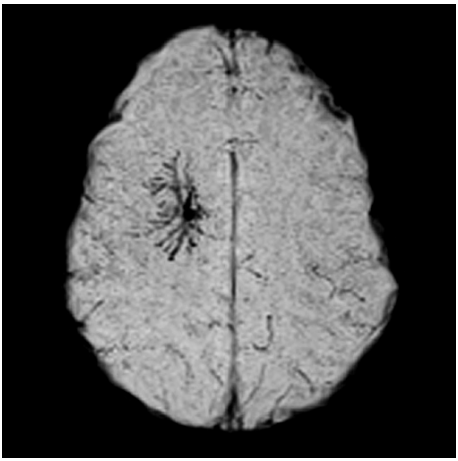
	csi_fid
TE variable	–[b]
Mixing time (TM) variable	–
Bandwidth variable	✓
Spectral fat suppression	–
Saturation regions	–
Averaging mode	Short term/ long term
Dimension	2D/3D
Phase cycling	–
Triggering	ECG/respiratory
2D PACE	–
k-space weighting	Full/elliptical/ weighted
Excitation of VOI	–
Multiple measurements	✓
AutoAlign	✓
Fully excited VOI	–
Water reference scan	–
Multinuclear support	✓

[a] only available at systems with a field strength of 3 T

[b] TE is automatically set to the minimum and cannot be changed

Susceptibility-weighted imaging (SWI)

Venous vessels as well as hemorrhages in the human brain may be displayed with susceptibility-weighted imaging. For this purpose, the different magnetic characteristics of deoxygenated blood and normal brain tissue are used.



Method

For data acquisition, a high-resolution 3D gradient echo sequence with echo times of 40 ms at a field strength of 1.5 T or 20 ms at 3 T is used. Using the long echo times, the MR signals in venous blood and normal brain tissue are able to create a phase difference. This phase difference is used for contrasting where veins and hemorrhages are shown as dark.

Image reconstruction

Two image series are computed In the **Magnitude** reconstruction mode:

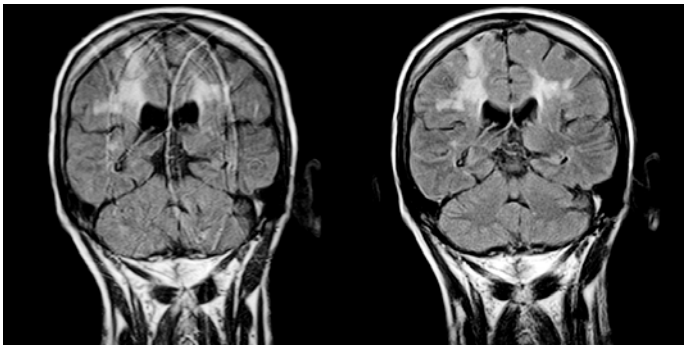
- MIP reconstructions of the SWI images across eight slices each (Sliding Window mode)
- SWI images without MIP reconstruction

In the **Magnitude/Phase** reconstruction mode, two more are computed in addition to the above mentioned image series:

- Conventional magnitude images
- Phase images

BLADE: Application/sequence description

The BLADE technique helps reduce the motion sensitivity of MR examinations. BLADE is available for the tse sequence.



left: without BLADE; right: with BLADE

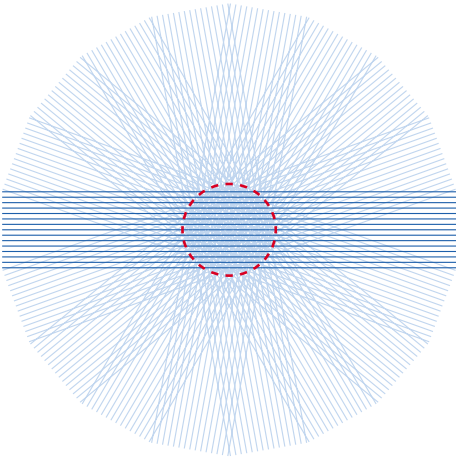
Use

- improves image quality in case of uncooperative patients
- T1, T2 weighting, STIR, dark fluid
- respiratory-triggered, abdominal measurements with 2D PACE

Sequence description

When using the BLADE technique, each echo train of the sequence generates a low-resolution image. The phase-encoding direction of this image is turned from one excitation to the next. Subsequently, the individual, low-resolution images are combined into a high-resolution image.

Sampling of the k-space with BLADE: Each echo train fills an individual stripe, the so-called blade



Example: Coverage of the k-space by 9 BLADES that contain 15 phase encoding lines each. The center of the k-space (red circle) is sampled again with each blade.

BLADE: Sequence parameters

In the **Resolution/Common** parameter card

- Trajectory: BLADE
- BLADE coverage: determines the number of blades with different rotation angles
  100%: the circle in the k-space is completely filled
  > 100%: the blades overlap
  the SNR improves
  < 100%: the k-space is not completely covered; shorter measurement time, however, poorer image quality

In the **Sequence/Part 2** parameter card

- Turbo factor: number of lines per blade (if GRAPPA is not used)
- Motion correction On:
  Corrects patient motion within the image plane (in-plane) which happens between the acquisition of two blades

Use motion correction only for rigid body motion (e.g., at the head), but not for abdominal imaging, for example.

BLADE: Application notes

1: To use BLADE as trajectory, the turbo factor has to be ≥ 9.

2: To use motion correction, the turbo factor has to be ≥ 28.

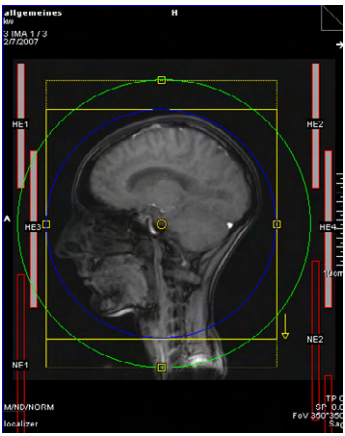
3: The accuracy of the BLADE reconstruction depends on the turbo factor. This is why BLADE protocols have a higher turbo factor and shorter echo spacing than a conventional TSE protocol with the same echo time.

4: For matrix sizes up to 320 and without GRAPPA, the images are usually available immediately or shortly after the measurement. Larger matrix sizes or the use of GRAPPA delay image reconstruction.

5: When using GRAPPA, the number of reference lines has to be considerably lower than the turbo factor (typically 8–12 as compared to 24 for conventional TSE imaging).

5: The *true* FOV of the sequence is *not* displayed. It corresponds to the blue circle in the square FoV (visible with graphic slice positioning). In the figure, the true expanded FoV (with phase-oversampling) is shown as a green circle. Due to the different phase-encoding directions of the individual blades, anatomy outside the true expanded FoV is aliased.

Avoiding aliasing: Use phase-oversampling.



Use phase-oversampling to avoid aliasing of the neck. The elements of the neck coil should not be selected.

tse Dixon: Application

tse Dixon is a water-fat separation technique based on the 2D tse sequence. The Dixon technique can be used as an alternative to FatSat.

Use

- T1, T2, and PD weighting
- Compatible with multi-coil acquisition and iPAT (GRAPPA)

Advantages

- Up to four contrasts are possible within one measurement (in-phase, opposed-phase, water, and fat images)
- Less sensitive to B0 and B1 inhomogeneities
- Improved outcome with MR-conditional implants[a]

[a] Please adhere to all safety instructions regarding implants (-> Operator Manual - MR System)

Image examples:
top left: reliable FatSat
top right: with MR-conditional implants
bottom left: fat image
bottom right: water image

tse Dixon: Sequence description/ sequence parameters

Sequence description

As compared to conventional se or tse sequences, an opposed-phase gradient echo is acquired besides the original in-phase spin echo. The echoes are obtained at the time when the phase shift between water and lipid is "-π" or "0", respectively. After a linear combination of the images with phase correction, water and fat selective images can be computed.

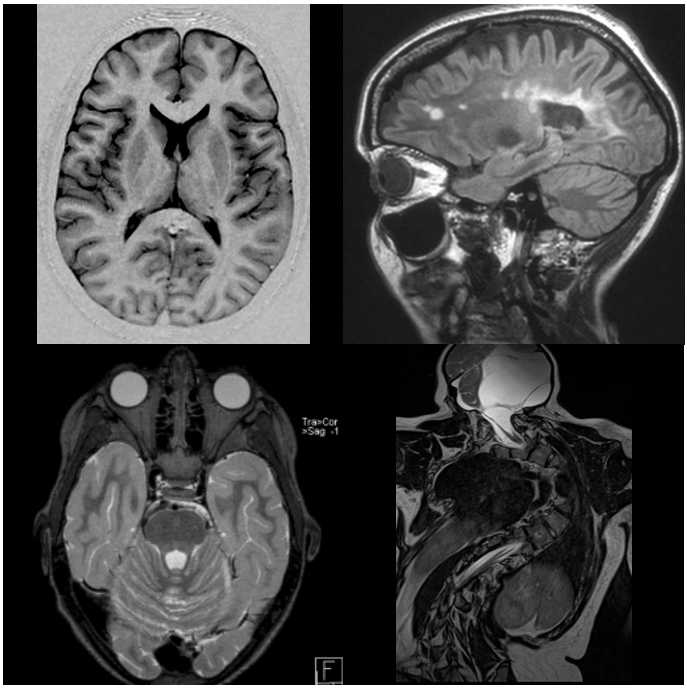
In the **Contrast/Common** parameter card

Dixon	**Determines whether fat and water images are displayed separately**
None	Dixon method is not applied
Water	Dixon method is performed and an image is reconstructed that contains the water signal only
Fat	Dixon method is performed and an image is reconstructed that contains the fat signal only
Water + fat	Dixon method is performed and two images are reconstructed: one image contains only the water signal, the other only the fat signal
Save original images	Saves also in-phase and opposed-phase images besides separated water and fat images

SPACE: Application

Neuro imaging

- Brain: isotropic resolution
- Brain: Measurements with thicker, contiguous slices
- Inner ear: High resolution
- Spine: in place of several 2D acquisitions

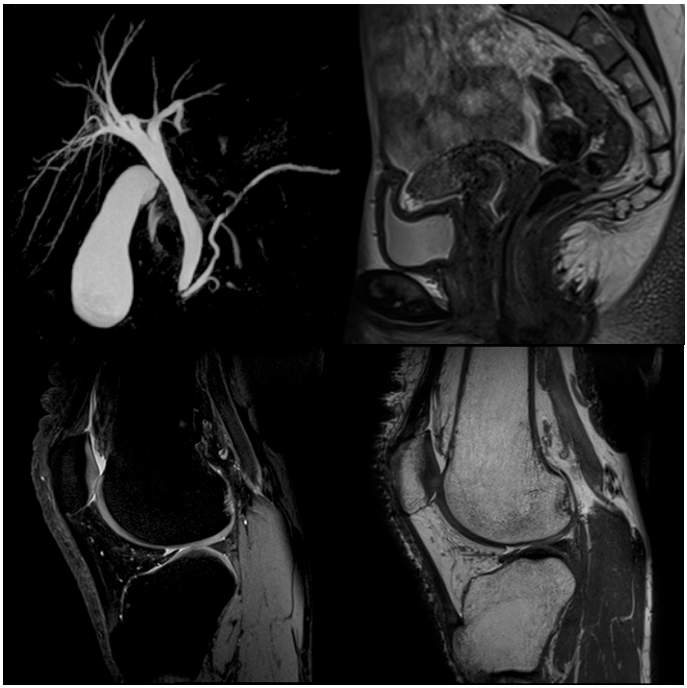


Body imaging

- Pelvis: in place of several 2D acquisitions
- PACE MRCP during free breathing

Ortho imaging

- PD and T1 weighting with isotropic, high-spatial resolution (with or without fat suppression)



SPACE: Sequence description/protocols

The SPACE sequence is a variant of the 3D Turbo spin echo sequence. As compared to a conventional TSE sequence, SPACE uses non-selective, short refocusing pulse trains that consist of refocusing pulses with variable flip angles. This allows for very high turbo factors (>100) and high sampling efficiencies. As a result, you obtain high-resolution, isotropic images that allow free reformats in all planes.

Optimized protocols

The following applications in the Siemens protocol tree include optimized SPACE protocols:

- Head: T1, T2, dark fluid, Double Inversion Recovery, and TrueIR contrast
- Spine: T2 contrast
- Body: T2 contrast, MRCP
- Ortho: PD and T1 contrast (with and without fat suppression)

SPACE: Sequence parameters

In the **Sequence/Part 2** parameter card

- Turbo factor:
  Number of RF refocusing pulses along the echo train
- Echo train duration:
  Total duration depending on turbo factor and echo spacing
- Non-selective excitation:
  Excitation and refocusing pulses
- Selective excitation:
  Excitation pulse is slice-selective, refocusing pulses are non-selective, number of averages = 2 with phase cycling to reduce artifacts, uneven number of averages possible to reduce the measurement time, that is, averaging only across the central phase-encoding lines

Flip angle mode	
Constant	Constant flip angle across the entire echo train. For heavily T2-weighted images (e.g., inner ear, MRCP) or PD- and T2-weighted imaging of the body.
PD var	Variable flip angle across the echo train. For short echo times.
T2 var	Variable flip angles across the echo train that affect strong dephasing of the flowing spins (dark blood, suppresses flow artifacts) and a low SAR. For T2 and dark fluid head imaging.To obtain T2 contrast comparable to that obtained with a conventional TSE sequence, a longer effective echo time has to be used.
T1 var	Variable flip angle across the echo train. For short echo times and T1-weighted contrast.

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