

# i\_Space 1.5T Plus

## Datasheet



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## I. MRI System Hardware and Auxiliary Equipment

### 1.1 Magnet System

WDM i\_Space 1.5T superconducting magnet utilizes the cutting-edge magnet manufacturing technology, in conjunction with a Japanese Sumitomo 4K cold head, to ensure zero liquid helium boil off (zero evaporation). Under normal operating conditions, it requires no helium refills for 3 to 5 years, significantly reducing hospital operational costs and downtime because of helium replenishment. With a state-of-art design, engineering and advanced alloys, the WDM superconducting magnet achieves industry-leading levels of magnetic field homogeneity while also minimizing patient claustrophobia. This provides a robust hardware platform for achieving exceptional clinical images and advanced imaging functionality.

It has the following main characteristics:

- Magnet: 1.5T superconducting magnet, active shielding;
- Shimming: Passive + Active + Dynamic;
- Cold head: 4K cold head, zero boil off (zero liquid helium consumption\*);
- Liquid helium filling cycle: no consumption during normal performance\*;
- Liquid helium capacity:  $\leq 1300\text{L}$ ;
- Patient aperture: 60cm;
- Magnetic field stability:  $\leq 0.1\text{ppm/h}$ ;
- Magnetic field homogeneity:

	Typical Value (ppm)	Guaranteed Value (ppm)
@10cm DSV	0.0018	0.02
@20cm DSV	0.016	0.05
@30cm DSV	0.04	0.2
@40cm DSV	0.20	0.7
@45cm DSV	0.50	1.8
@50cm DSV	0.99	2.0

- Magnet length: 157cm;
- Weight:  $\leq 3800\text{kg}$ ;
- Fringe field (0.5 Gauss line rang): Axial 4 meters; Radial 2.5; (4m x 2.5m).
- Passive shimming and dynamic shimming to ensure high magnetic field uniformity;
- Liquid helium refill period: longer than 36 months (no consumption during normal operation, only replenished when replacing the cryocooler).

### 1.2 Magnet Monitoring

The magnet remote monitoring system can use GSM or WLAN network to remotely monitor the magnet status in operation. When the pressure, or temperature and/or power supply of the magnet refrigeration system fails, the SVU will automatically notify the service team and the hospital by message, to avoid loss of liquid helium caused by the refrigeration system failure.

## 1.3 Gradient System

The first-class gradient system with leading design has active eddy current shielding technology, water cooling, dynamic shimming technology and strong performance. Independent water-cooling channels simultaneously cool the primary and secondary coils, ensuring the highest performance for clinical applications. It can easily meet the clinical applications that need to adopt fast and complex technologies, such as gradient echo sequence for dynamic enhanced scanning, single-breath hold liver thin-slice scanning and EPI imaging.

It has the following main characteristics:

- Maximum gradient field strength: 35 mT/m
- Maximum gradient switching rate: 175 mT/m/ms
- Minimum climbing time:  $\leq 0.2$ ms;
- Duty cycle: 100%;
- Cooling mode: water cooling;
- Scanning field: 0.5cm-55cm;
- Minimum 2D slice thickness:  $\leq 0.1$ mm;
- Minimum 3D slice thickness:  $\leq 0.05$ mm.

## 1.4 Spectrometer and RF System

The spectrometer is the core of MRI system, with the most sophisticated MRI technology applied. The R & D ability of spectrometer is the most important embodiment of the manufacture's R&D ability. Mainstream MRI manufacturers use self-developed spectrometer systems. The superconducting MRI system spectrometer independently developed by WDM is a practice of the most advanced and latest electronic technology: it can be configured with 8 to 32 channels; it supports full-digital RF transmitting and receiving; it adopts LVDS high-speed serial transmission technology and FMC high-speed data transmission connection technology, with strong scalability; the MRI-specific electronic chip with high signal-to-noise ratio, low power consumption and zero-magnetism is adopted; its high-precision sequence management, self-developed homologous phase coherence technology, transmit and receive coils share the same local oscillator, allows for good phase consistency and removal of frequency winding. It has the advantages of stable performance, easy-to-use, simple-to-operate, guaranteeing for satisfactory imaging speed and quality.

It has the following main characteristics:

- RF amplifier power: 20KW;
- Digital signal processing frequency: 63.87MHz $\pm$ 300KHz;
- Transmission bandwidth: 600KHz;
- Receiving channel: 24 channel, with FMC technique that allows for realization of arbitrary channel expansion;
- Receiving bandwidth: 1MHz that provides fast sampling speed and high signal-to-noise ratio;
- Receiving dynamic range:  $\geq 165$ dB;
- Oversampling Technique: 100mHz, high signal-to-noise ratio.

- Modulation mode: frequency, phase and amplitude;
- RF frequency and phase accuracy: 32bit and 16bit;
- RF and gradient waveform update rate: 2us/1us;
- Gradient output channels: X, Y, Z and B<sub>0</sub>;
- Gradient Pre-Emphasis: X/Y/Z each axis has 9 groups of direct compensation items and B<sub>0</sub> compensation items, and 4 groups of cross items;
- Homologous phase coherence technique: phase fluctuation  $\leq 0.01^\circ$ ;
- Digital dynamic range extension technique: significant bit 32bit;
- Optical fiber technique: optical fiber acquisition, optical fiber gradient, no interference, low attenuation, with simple connection and stable performance.

## 1.5 Examination Environment

- Supports two-way communication
- Supports patient monitoring system
- Supports patient alarm device
- Supports patient emergency stop button
- Supports noise-canceling headset
- Wireless physiological signal monitoring system: respiration, ECG

## 1.6 Patient Table



The ergonomics-based table surface design as well as its stable and low-noise operation process offers patients a more comfortable experience. This 2D smart electric table can be controlled to move up and down, making it easy for patients to go up and off the table. Its bilateral positioning system makes operation easier for doctors and its imaging aperture is equipped with ventilation and lighting system to provide patients more comfort.

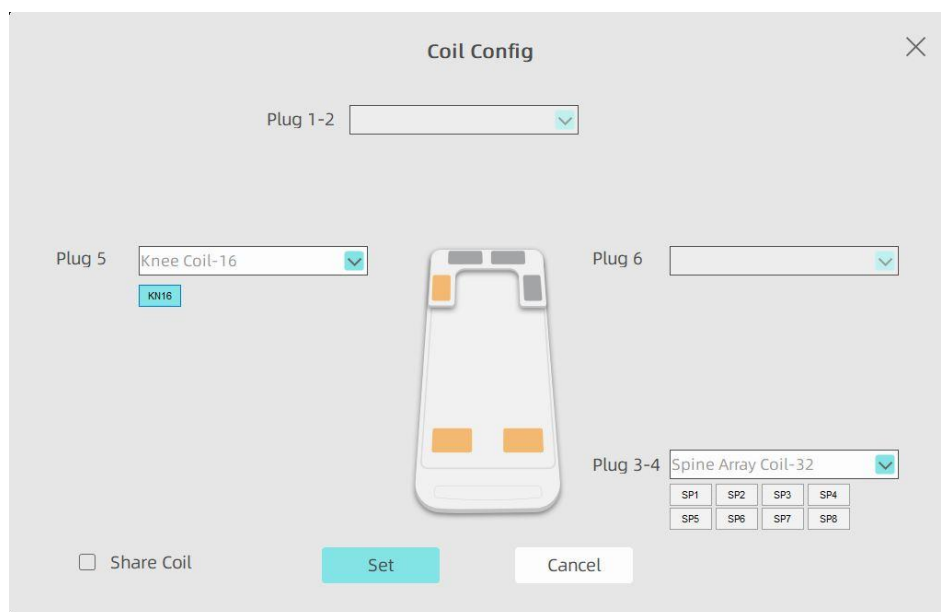
It has the following main characteristics:

- Size: 261cm x 65cm x 89cm;
- Maximum load-bearing capacity: 250kg;
- Positioning accuracy:  $\pm 0.5\text{mm}$ ;
- Maximum moving distance: longitudinal  $\geq 2400\text{mm}$ , up and down  $\geq 370\text{mm}$ ;
- An UI to control table movement: longitudinal automatic aperture entry and exit, and the scanning part reaches the center of the magnet;
- Maximum scanning range: 165cm;
- Maximum Horizontal moving speed: 20cm/s;
- Height range: 52cm at minimum, 90cm at maximum;

## 1.7 Integrated Receiving Coils

With coils highly integrated with the MRI system and high-density coil array embedded in the patient table, coil unit combinations can be switched to match the scanning position, allowing for high-quality and large-scale collective imaging. When the patient needs examination on multiple body parts, there is no need to replace coils one by one and reposition the patient repeatedly, which greatly shortens the examination time and significantly improves the scanning efficiency. Compared with the traditional targeting coils for each body part that are relatively heavier, the head and neck combined coil's lower part and the spinal coil have been embedded in the patient table, so that only the upper part of the head and neck coil upper part, abdominal coil and some optional coils that are lighter need to be operated to realize the scanning of all clinical parts of the body.

The currently connected coils can be automatically detected in the software UI.



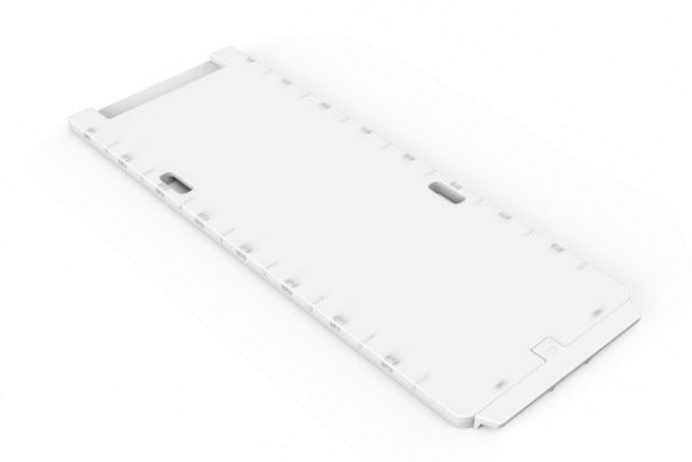
## 1.7.1 Standard Coils

### 1.7.1.1 24-Channel Head and Neck Combined Coil



- Size: 48cm x 36cm x 35cm;
- Weight: 6.6kg;
- Applicable body parts: head, neck, spine, head and neck blood vessels;
- Designed to be inserted into the patient table, the coil is often placed on the table and does not need to be moved in most cases;
- With optimal design of the 24 unit to provide top image quality, high definition, good uniformity, and large imaging scale;
- With large internal space capacity, fulfilling the safety requirements of wearing headphones;
- Design of opening up and down, blind navigation, cushion optimization design, simple and comfortable placement of patients;
- Units fully decoupled to provide superior parallel accelerated imaging.

### 1.7.1.2 24-Channel Spine Coil



- Size: 99cm x 46.5cm x 3.4cm;
- Weight: 7.3kg;

- Applicable body parts: upper and lower abdomen, spine;
- Designed with patented direct vertical insertion into patient table, providing more operation convenience and reliability;
- Working seamlessly with the head and neck combined coil to cover a wide range of imaging from head to pelvic cavity;
- Composed of 6 sections with 4 units in each group, the coil can provide whole spine splicing imaging by positioning the patient simply and comfortably at one time;
- Supports automatic switch between coil combinations to save spectrometer channel resources to the greatest extent;
- The coil thickness is only 34mm, far less than any similar product in the industry, improving patient comfort.

### 1.7.1.3 12-Channel Body Coil (2 sets for whole body DWI)



- Size: 58.5cm x 44.5cm x 2.9cm;
- Weight: 2.3kg;
- Applicable body parts: upper and lower abdomen, hip, etc.;
- Large coverage: full abdominal coverage at one time, covering both upper and lower abdominal scanning so that the coil does not have to be re-placed;
- Meet the requirements of fetal imaging for pregnant patients;
- Built from soft EVA material that allows for fast, convenient and stable placement;
- Designed into separate sections for automatic switch among coil combinations, saving the spectrometer channel resources to the greatest extent.

### 1.7.1.4 16-Channel Knee Coil



- Size: 33.5cm x 29cm x 27.5cm;
- Weight: 6.4kg;
- Applicable body parts: knee, ankle, elbow, etc.;
- With patented design of seaming to the patient table's baseboard + one-press double locking (upper and lower coil covers, left and right positions) ensures the stability of coil position during scanning and reduces artifact possibilities;
- With patented design of the inner surface fitting human body's physiological curvature, the coil is advantaged in completing meniscus and cruciate ligament scans with normal physiological positions, ensuring patient comfort and reducing artifact possibilities;
- With the patented coil top edge design that conforms to the physiological angle of the foot and ankle area, the coil is advantaged in completing scans when lack of a separate ankle coil, and it can fix joints' position and reducing motion artifact possibilities during scanning.

### 1.7.1.5 8-Channel Flexible Coil



- Size: 50cm x 29cm x 2.5cm;
- Weight: 1.3kg;
- Applicable body parts: acral joints, etc.;
- Build from light and thin EVA material, easy and durable for bending;
- With strap limit hole that facilitates fast and stable coil binding.

### 1.7.1.6 8-Channel Shoulder Coil



- Size: 33cm x 42cm x 31.5cm;
- Weight: 4.6kg;
- Applicable body part: shoulder;
- Easy to switch the coil position for left and right shoulder joints;
- Quickly lock the positioning baseplate to reduce shoulder motion artifacts;
- Equipped with special shoulder cushion to improve patient comfort

### 1.7.2 Optional Coils

In addition to standard coils above, there are ten optional coils that can be equipped according to the hospital's characteristic departments, such as breast coil, ankle coil, wrist coil, betc. Introduced below are the main optional coils supported by the system.

#### 1.7.2.1 8-Channel Knee Coil



- Serial No: WD-RCK-1.5B
- Size: 22cm x 24cm x 26cm;
- Weight: 2.6kg;
- Applicable body parts: knee, ankle, elbow, etc.;
- With patented design of seaming to the patient table's baseboard + one-press double locking (upper and lower coil covers, left and right positions) ensures the stability of coil position during scanning and reduces artifact possibilities;
- With patented design of the inner surface fitting human body's physiological curvature, the coil is advantaged in completing meniscus and cruciate ligament scans with normal physiological positions, ensuring patient comfort and reducing artifact possibilities;

- With the patented coil top edge design that conforms to the physiological angle of the foot and ankle area, the coil is advantaged in completing scans when lack of a separate ankle coil, and it can fix joints' position and reducing motion artifact possibilities during scanning.

### 1.7.2.2 8-Channel Wrist Coil



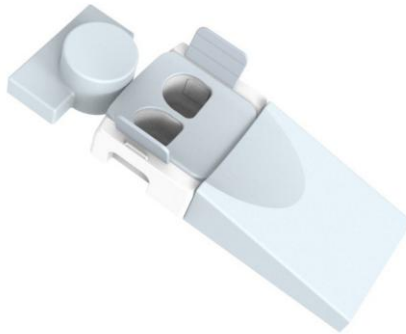
- Size: 32cm x 25cm x 16.2cm;
- Weight: 6.1kg;
- Applicable body parts: wrist, palm;
- Semi-open design, as well as flexible and convenient operation;
- Ultra-high signal-to-noise ratio, excellent image uniformity and outstanding lipid suppression effect;
- Special hand fixed cushion to reduce motion artifacts.

### 1.7.2.3 16-Channel Wrist Coil



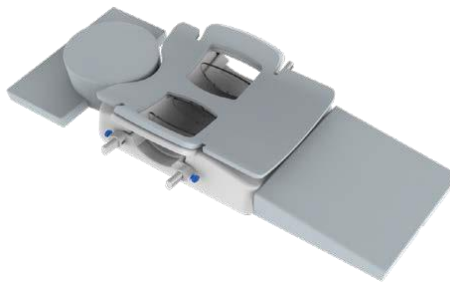
- 16-Channel Version Serial No.: WD-RCW-16-1.5A
- Size: 32cm x 25cm x 16.2cm;
- Weight: 6.1kg;
- Applicable body parts: wrist, palm;
- Semi-open design, as well as flexible and convenient operation;
- Ultra-high signal-to-noise ratio, excellent image uniformity and outstanding lipid suppression effect;
- Special hand fixed cushion to reduce motion artifacts.

### 1.7.2.4 16-Channel Breast Coil



- Serial No.: WD-RCBR-16-1.5A
- Dimensions: 40cm x 48cm x 30cm;
- Weight: 3.6kg;
- Applicable body part: breast;
- Compatible with unilateral or bilateral imaging modes, providing excellent image signal-to-noise ratio and uniformity;
- Designed with a closed structure and equipped with compression positioning frame;
- Equipped with a head cushion to improve patient comfort (or optional adjustable head support frame).

### 1.7.2.5 8-Channel Breast Coil



- Size: 50cm x 44cm x 22cm;
- Weight: 5kg;
- Applicable body part: breast;
- Compatible with unilateral or bilateral imaging mode, with good image signal-to-noise ratio and uniformity;
- Adopted open design and positioning bracket support;
- Equipped with head cushion to improve patient comfort.

### 1.7.2.6 8-Channel Flexible Coil(small)



- Size: 18cm(L) ×36cm (W) ×1.6mm (H)
- Weight: 1.0kg;
- Applicable body parts: acral joints, etc.;
- Build from light and thin EVA material, easy and durable for bending;
- With strap limit hole that facilitates fast and stable coil binding.

### 1.7.2.7 4-Channel Shoulder



- WD-RCSH-4-1.5A
- Size: 33cm x 23cm x 27cm;
- Weight: 1.6kg;
- Applicable body part: shoulder;
- Fully wrapped coil,
- maximum fit of the shoulder joint, reduce the volume ratio, effectively improve the imaging signal-to-noise ratio

### 1.7.2.8 8-Channel Ankle Coil



- Size: 34cm x 20cm x 36cm;
- Weight: 5.9kg;
- Applicable body parts: ankle and sole;
- Patient's ankle placement angle can be adjusted in a wide range, significantly improving patient comfort;
- The bottom bracket and the coil are designed separate from each other to provide more convenience for patient positioning.

### 1.7.2.9 16-Channel Infant Body Coil



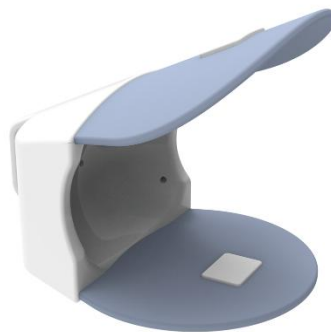
- 16-Channel Version Serial No.: WD-RCBDI-16-1.5A
- Size: 75.5cm x 31cm x 25cm;
- Weight: 4.5kg;
- Applicable body parts: infant body;
- Equipped with infant mobile tray to avoid infant movements and reduce accidents;
- Highly fit for infants.

### 1.7.2.10 16- Channel Ankle Coil



- 16-Channel Version Serial No.: WD-RCAN-16-1.5A
- Size: 34cm x 20cm x 36cm;
- Weight: 5.9kg;
- Applicable body parts: ankle and sole;
- Patient's ankle placement angle can be adjusted in a wide range, significantly improving patient comfort;
- The bottom bracket and the coil are designed separate from each other to provide more convenience for patient positioning.

### 1.7.2.11 16-Channel Shoulder Coil



- Serial No.: WD-RCSH-16-1.5A
- Dimensions: 32cm x 27cm x 26cm;
- Weight: 1.8kg;
- Applicable body parts: shoulder;
- Easy to switch between left and right shoulder positions;
- Better fitting to the shoulder, offering better image quality;
- With specially designed soft coil for shoulder joint for better patient comfort.

### 1.7.2.12 12-Channel Shoulder Coil



- Size: 27cm(L) ×22cm(W) ×28.6cm (H)
- Weight: 1.8kg;
- Applicable body part: shoulder;
- Easy to switch the coil position for left and right shoulder joints;
- Quickly lock the positioning baseplate to reduce shoulder motion artifacts;
- Equipped with special shoulder cushion to improve patient comfort.

## .8 Image Acquisition Workstation

- Based on Windows®10 professional computer system and Windows ® user interface;
- The computer uses Intel ® Core TMI 9 processor, maximum dominant frequency  $\geq 5.2$ GHz, memory  $\geq 32$ GB, dual hard disk setting, solid state drive  $\geq 256$ GB, 7200rpm mechanical hard disk  $\geq 2000$ GB, storage more than 10 million uncompressed images of 256x256 matrixes; GT730 and 5G video memory for standard provision, RTX3060 and 12G video memory for advanced provision, and the reconstruction speed is  $\geq 30000$ FFT/s (resolution: 256x256 FOV)
- The integrated DVD recorder has a storage capacity of 4.7GB, and the disc has its own image browsing software, which allows for DICOM image browsing on any other Windows computer;
- With one 21.3-inch 2M-pixel LCD medical display (resolution 1600 × 1200) ;
- With one 24-inch 2M-pixel LCD (resolution: 1920 × 1200) ;
- DICOM 3.0 standard transmission, reception, query, and storage, basic printing of DICOM laser camera;
- The internal communication system includes: communication system of the operation table, volume control of the microphone and earphone in the scanning room, volume control of the microphone in the operation room, and the connection of the high-fidelity stereo system for playing music.

## 1.9 Clinical Imaging Parameters

- Maximum FOV: 55cm
- Minimum FOV: 0.5cm
- Minimum 2D slice thickness:  $\leq 0.1$ mm
- Minimum 3D slice thickness:  $\leq 0.05$ mm

- Minimum TR (128x128) for SE sequence:  $\leq 2.23\text{ms}$
- Minimum TE (128x128) for SE sequence:  $\leq 1.36\text{ms}$
- Minimum TR (256x256) for SE sequence:  $\leq 3.5\text{ms}$
- Minimum TE (256x256) for SE sequence:  $\leq 2\text{ms}$
- Minimum TR (128x128) for FSE sequence:  $\leq 6\text{ms}$
- Minimum TE (128x128) for FSE sequence:  $\leq 2.4\text{ms}$
- Minimum ESP (128x128)  $\leq 2.2\text{ms}$
- Minimum TR (256x256) for FSE sequence:  $\leq 6.5\text{ms}$
- Minimum TE (256x256) for FSE sequence:  $\leq 2.6\text{ms}$
- Minimum ESP (256x256):  $\leq 2.4\text{ms}$
- Maximum ETL:  $\geq 1024$
- Minimum TR (128x128) for 2D GRE sequence:  $\leq 0.75\text{ms}$
- Minimum TE (128x128) for 2D GRE sequence:  $\leq 0.14\text{ms}$
- Minimum TR (256x256) for 2D GRE sequence:  $\leq 1.34\text{ms}$
- Minimum TE (256x256) for 2D GRE sequence:  $\leq 0.49\text{ms}$
- Minimum TR (128x128) for 3D GRE sequence:  $\leq 1.04\text{ms}$
- Minimum TE (128x128) for 3D GRE sequence:  $\leq 0.38\text{ms}$
- Minimum TR (256x256) for 3D GRE sequence:  $\leq 1.25\text{ms}$
- Minimum TE (256x256) for 3D GRE sequence:  $\leq 0.4\text{ms}$
- Minimum TR (128x128) for EPI sequence:  $\leq 1.6\text{ms}$
- Minimum TE (128x128) for EPI sequence:  $\leq 0.65\text{ms}$
- Minimum TR (256x256) for EPI sequence:  $\leq 1.62\text{ms}$
- Minimum TE (256x256) for EPI sequence:  $\leq 0.66\text{ms}$
- Maximum ETL for EPI sequence: 512
- Maximum diffusion-weighted B-value:  $10000\text{s/mm}^2$
- Maximum acquisition matrix: 1024
- Minimum within-layer resolution:  $\leq 0.1\text{mm}$

## II. Standard Clinical Application Packages / Sequences / Techniques

### 2.1 Clinical Application Packages

#### 2.1.1 Neurology

Neural application components are sequences, protocols, and workflows optimized specifically for nervous system scanning. Conventional application technique with high signal-to-noise ratio such as SE, FSE, and GRE sequences can achieve the highest lesion detection rate. According to the level of patient cooperation, a targeted high-resolution and rapid protocol has been developed. The package includes:

- T1WI images with good gray-white matter contrast obtained based on SE sequence, and flow compensation technique to reduce the vascular pulsation artifacts after enhancement;
- High resolution and fast imaging realized based on FSE sequence, and the technique of driven balance and flow compensation to increase the brightness of CSF;
- T2 FLAIR to inhibit the cerebrospinal fluid signal and highlights the lesions in the brain parenchyma, with T2WI as basis;
- T1 FLAIR to inhibit the cerebrospinal fluid signal and to increase gray-white matter contrast with the T1WI as basis;
- DWI to obtain high-quality conventional diffusion-weighted head images, equipped with automatic post-processing technique. ADC and EADC maps are automatically calculated after scanning. This technique can be utilized to detect acute and hyperacute cerebral infarction;
- 3D T1 fast inversion recovery isotropic volumetric brain imaging;
- High-resolution volumetric inner ear imaging based on 3D FSE, 3D ISO echo train modulation sequence, or 3D bSSFP;
- The dynamic analysis software to analyze the T2\* data dynamically collected by EPI, so as to obtain correlation negative enhancement parameter figures;
- DSC (Dynamic Susceptibility-weighted Contrast-enhanced) to obtain perfusion parameters such as cerebral blood volume (CBV) and cerebral blood flow (CBF) by dynamically analyzing the effect of contrast agent on tissue signal during its first circulation in intracranial vessels, which mainly can be used for the diagnosis of acute stroke and glioma;
- Brain DTI (Diffusion Tensor Imaging, a derivative of DWI) to reflect the structural and anisotropic characteristics of white matter fiber bundles in the brain through the diffusion movement of water molecules. After scanning, Mean Diffusivity (MD) , Apparent Diffusion Coefficient (ADC) , Exponential Apparent Diffusion Coefficient (eADC) , Axial Diffusivity (AD) , Radial Diffusivity (RD) , Volume Ratio (VR) , Fractional Anisotropy (FA) , and Color FA Map are automatically calculated;
- Automatic patient table multistep moving for whole spine imaging; whole spine image stitching with image stitching post-processing technique;

- When applying DIR and TIR, in the black blood sequence, blood flow shows low signal due to the suppression and blood vessel walls are highlighted. This technique can also be used for observing certain specific tissues and eliminating interference signals caused by blood flow.
- PRESS is used for analyzing the content of metabolites in the human body.
- MEDIC is a T2\*WI sequence, where joint fluid shows high signal and articular cartilage shows slightly higher signal, making it easy to display defects on the joint surface.
- SWI is an imaging technique that is highly sensitive to subtle local magnetic field changes, such as deoxyhemoglobin, tissue iron deposition, or calcification. It has become an important means of examining intracranial venous structures and related diseases involving iron deposition.
- TURBINE can eliminate motion artifacts and obtain diagnostically valuable images.
- Gray-white matter imaging is highly significant to lesion diagnosis occurring in the gray and white matter of the brain.
- T2Mapping can measure the T2 value of tissues and perform quantitative evaluations of bone and joint cartilage properties, as well as myocardial tissue.
- MultiQuant Technique (MQT) is a novel MR imaging method that allows the acquisition of almost all contrast information used in clinical practice in a single scan, based on quantitative information of relaxation rates and proton density.
- MRM, based on SSFSE, is used for imaging of the spinal cord and vertebral canal.
- 3D ASL, a non-invasive arterial blood flow measurement based on nuclear magnetic flow labeling and can be used for stroke and tumor research.

## 2.1.2 Body

The body application package is the sequence, protocol and workflow specifically optimized for body scanning, which is especially suitable for chest, abdomen and pelvic examination. Both breath-hold and breath-trigger protocols can obtain optimized high-resolution body images. It mainly includes:

- Multiple breath-hold techniques or breath-trigger techniques were used for motion inhibition;
- Single echo T1WI based on 2D GRE sequence;
- Dual echo in phase and inverse phase T1WI based on 2D GRE sequence;
- T2WI based on FSE and SSFSE under breath hold or breath trigger;
- T2WI is obtained and motion artifacts are eliminated based on FSE and propeller-style k-space filling;
- MRCP and MRU: 2D thick-slice breath-hold imaging based on SSFSE sequence; 3D imaging based on FSE 3D sequence, utilizing respiratory gating technique;
- Dynamically enhanced abdomen scan based on 3D VALUE;
- 2D and 3D bSSFP for high-resolution rapid imaging with or without breath-holding;
- 2D FSE+DIXON; four sets of contrast images are obtained in a single scan, insensitive to magnetic field inhomogeneity, suitable for fat suppression in areas such as the pelvis;
- 2D FSE with dual echo trains achieves image acquisition of both PD and T2-weighted images in one scan;
- Multi-b-value whole-body diffusion imaging, with up to 16 configurable b-values;

- 3D Renal Angiography of Flow-In Steady-State Precession Imaging (3D RAFISP) based on 3D bSSFP for diagnosis of diseases like renal artery stenosis;
- 2D PC for quantitative analysis of blood flow;
- CEMRA shortens blood T1 values significantly using a bolus contrast agent, shorter than other tissues, using ultra-fast T1WI for imaging;
- Body vascular plaque imaging based on FSE;
- bSSFP, high-resolution fast imaging with breath-hold or free breathing;
- Pelvic dynamic enhancement scan based on 3D VALUE;
- T1WI and T2WI optimized specifically for male or female pelvic cavity;
- T1WI and T2WI optimized specifically for fetal imaging;
- Body diffusion imaging;
- Lipid Quantification Technique (LITE) ;
- The dynamic positive enhancement curve analysis conducted by dynamic analysis software to the positive enhancement parameter figure.

### 2.1.3 Oncology

Tumor application package is the sequence, protocol and workflow optimized specifically for tumor scanning. It is highly sensitive to tumors and greatly improves the detection rate of small lesions. This component mainly includes:

- STIR, GRE in phase and out of phase protocol, which is highly sensitive to tumors;
- Dynamic imaging to help localize and characterize lesions;
- The high-resolution dynamic enhanced scanning protocol based on 3D VALUE sequence to provide satisfactory fat suppression effect;
- Whole-body diffusion, for early diagnosis and differential diagnosis of tumors;
- Multi-b-value DWI;
- The dynamic positive enhancement curve analysis conducted by dynamic analysis software to provide the positive enhancement parameter figure.

### 2.1.4 Breast

The Breast application package is the sequence, protocol and workflow optimized specifically for breast scanning. With perfect multi-directional and large-scale fat suppression technique, high-resolution dynamic enhancement, patients' pathophysiological information can be completely reproduced. It mainly includes:

- FSE-based T1 and T2 high-resolution scanning protocol;
- T2 Mapping for quantitative analysis of the breast;
- DIXON, obtaining four sets of contrast images in one scan, insensitive to magnetic field inhomogeneity;
- High-resolution multi-phase dynamic contrast-enhanced scanning protocol based on 3D VALUE sequence, achieving uniform fat suppression effect;

- The high-resolution dynamic enhanced scanning protocol based on 3D VALUE sequence to achieve uniform fat suppressing effect;
- For fatty breasts and silicone prosthesis, the system can accurately find the water peak with designated frequency search modes;
- The frequency confirmation workflow allows the user to confirm the frequency before starting the scan;
- Supports breast multi b-value diffusion imaging;
- Supports Silhouette, MPR, MIP and other functions;
- Auto SUB and Auto MIP: after scanning, the pre- and post-enhancement images are automatically silhouetted, and the silhouetted images are automatically processed by MIP;
- The dynamic curve analysis of positive enhancement conducted by the dynamic analysis software to obtain the positive enhancement parameter figure and enhancement curve.

### 2.1.5 Spine

- T1, T2, PD high-resolution scanning protocol based on FSE;
- T2Mapping based on FSE, quantitatively evaluating changes in tissue water tissues, matrix tissues, and collagen structures;
- STIR, which can obtain more uniform vertebral fat suppression images;
- Spinal canal water imaging MRM, based on SSFSE;
- Multi-b-value DWI, up to 16 b-values can be set in one scan;
- Automatic stitching technology for whole spine imaging;
- Water-fat separation DIXON that allows four sets of contrast images in one scan;
- 3D GRE-based contrast-enhanced MR angiography CEMRA;
- TURBINE can reduce motion artifacts to some extent;
- 2D, 3D IR FSE can be used for peripheral nerve imaging;
- DTI technique based on SE EPI can be used for spinal cord imaging;
- High-resolution imaging based on bSSFP.

### 2.1.6 Angiography

The vascular application package is the sequence, protocol and workflow optimized specifically for vascular scanning to ensure rapid and high-resolution non-enhanced and enhanced vascular examination.

Non-enhanced vascular imaging technique includes TOF, PC, and renal arterial in-flow steady state precession enhanced angiography methods:

TOF (Time of Flight) is a vascular imaging method based on gradient echo technique. This imaging technique uses the inflow enhancement effect of blood flow and the saturation state of background tissue to form good blood-tissue contrast.

- 2D TOF is mainly used for the imaging of neck blood vessels and venous vessels with relatively straight direction;
- 3D TOF that is mainly utilized for head and neck artery imaging;
- The accompanying saturation zone technique is used to suppress the interference of arterial or venous signals;
- Tone pulse is utilized to reduce the boundary artifacts caused by flow saturation;
- Compressed sensing technique acceleration.

PC (Phase Contrast) is a method that suppresses the background tissue with flow rate as coding in order to highlight vascular signals.

- 3D PC for mobile and venous scanning, especially for the examination of cranial veins in clinic;
- The speed coding (VENC) in PC sequence can be freely adjusted in multiple directions;
- Compressed sensing technique acceleration.

Renal arterial in-flow steady state precession enhanced angiography utilizes the "triple brightness" characteristics of bSSFP.

- Combining water excitation technique and FLAIR technique to achieve non-contrast renal artery imaging.

Enhanced vascular imaging technique mainly includes:

The 3D fast phase disturbing gradient echo sequence specifically optimized for CEMRA can apply compressed sensing + parallel acquisition, partial echo, k-space bidirectional center sequencing, etc. collectively to ensure high contrast-to-noise ratio and realize fast acquisition:

- Bolus tracking workflow: a. performing fast dynamic scanning with bolus tracking protocol, and generating real-time dynamic images of the same slice in the target vessel for users to judge the arrival time of contrast agent; b. the scanning progress region highly visualizes the scanning process;
- Automatic patient table shifting workflow, with special scanning sequence and high-density receiving coil to realize peripheral vascular imaging;
- The blood vessels were visualized by silhouette, MIP, VRT, and SSD;
- Auto SUB and auto MIP, the pre- and post-enhanced images are automatically silhouetted after scanning, and the silhouetted images are automatically processed by MIP.

### 2.1.7 Orthopedics

Orthopedic application package is the sequence, protocol and workflow optimized specifically for orthopedical joint scanning. With extremely high magnetic field homogeneity, it can obtain high-quality orthopedic images with high-density coils, so that any tiny lesions in bone and joint can be presented by imaging. This package includes:

- High resolution T1, PD and T2 protocols based on 2D FSE sequence with or without fat suppression;
- 2D T2\* high-resolution imaging based on GRE sequence;
- High resolution fat suppression imaging based on 3D FSE sequence;

- High resolution imaging based on 3D FSE sequence;
- Satisfactory off-center fat suppression effects;
- Supports both strong and weak fat suppression;
- Fast water fat separation;
- MPR for multi-planar observation of isotropic acquired data.
- T2Mapping based on 2D FSE, can be used for quantitative analysis of water content changes in tissues;
- DIXON based on 2D FSE, achieving water-fat separation;
- Water imaging based on SSFSE;
- Multi-b-value DWI based on SE EPI;
- Contrast-enhanced MR angiography CEMRA based on 3D GRE;
- High-resolution imaging of joints based on bSSFP;
- TURBINE technology to reduce motion artifacts;
- 3DVALUE for enhancement.

### 2.1.8 Cardiac

The cardiac application package is a specialized sequence, protocol, and workflow optimized for cardiac scans. By controlling and tracking the motions of the heart and respiratory system, it enables anatomical planar imaging of cardiac function and presents pathological and physiological information of the patient's heart. This package mainly includes:

- "DarkBlood" technique that utilizes FSE sequence to suppress the bright signal from blood, allowing for clear delineation of the boundaries between the cardiac chambers, myocardium, and large vascular cavities;
- T1WI, T2WI, and STIR weighted imaging triggered by electrocardiography (ECG) , combined with double inversion recovery-based "Dark Blood" technique, for cardiac morphology imaging, which provides excellent contrast between myocardium, cardiac chambers, major blood vessels, and surrounding structures;
- CINE imaging that uses ECG-triggered 2D bSSFP sequence, effectively compensating for phase interference caused by spatial encoding gradient fields and maximizing the preservation of echo signal intensity. Bright blood can be observed in cardiac chambers and major blood vessels, providing good contrast for myocardium, cardiac chambers, major blood vessels, and surrounding structures. It serves as the foundation for cardiac function analysis.
- Cardiac flow velocity measurement using 2D phase-contrast technique;
- T1 Mapping technique for myocardium that quantifies the T1 value of each voxel in the myocardial tissue: normal myocardium has a certain T1 value, and it changes when there is myocardial edema, fibrosis, or infiltrative diseases. This technique can be used to detect focal or diffuse diseases;
- Myocardial T2 mapping technique, quantitatively assessing cardiac inflammation, myocardial injury, etc., offering high clinical value.

## 2.1.9 Fetus

- Multiple breath-hold technique or respiratory triggering technique for motion artifact suppression;
- Single-echo T1-weighted imaging based on 2D GRE sequence;
- Double-echo, in-phase and out-of-phase T1-weighted imaging based on 2D GRE sequence;
- FSE and propeller K-space filling technique to obtain T2-weighted imaging and to eliminate motion artifacts;
- MRCP and MRU, 2D imaging based on breath-hold slab scans with SSFSE; 3D imaging based on FSE sequence utilizing respiratory gating;
- Abdominal dynamic contrast-enhanced scan based on 3D VALUE;
- 2D and 3D bSSFP, high-resolution rapid imaging with or without breath holding;
- Dixon water-fat separation imaging based on 2D FSE, obtaining four sets of contrast images in one scan, insensitive to magnetic field inhomogeneity;
- Double-echo 2D FSE, obtaining PD and T2-weighted images in a single acquisition;
- Multi-b-value diffusion imaging, with up to 16 configurable b values;
- CEMRA, using bolus injection of contrast agent to significantly shorten blood T1 values and to make it shorter than other tissues, with ultra-fast T1-weighted imaging;
- 2D PC for quantitative analysis of blood flow.

## 2.1.10 Children

- Multiple breath-hold technique or respiratory triggering technique for motion artifact suppression;
- Single-echo T1-weighted imaging based on 2D GRE sequence;
- Double-echo, in-phase and out-of-phase T1-weighted imaging based on 2D GRE sequence;
- FSE and propeller K-space filling technique to obtain T2-weighted imaging and to eliminate motion artifacts;
- MRCP and MRU, 2D imaging based on breath-hold slab scans with SSFSE; 3D imaging based on FSE sequence utilizing respiratory gating;
- Dynamic contrast-enhanced body scan based on 3D VALUE;
- 2D and 3D bSSFP, high-resolution rapid imaging with or without breath holding;
- T1WI and T2WI optimized specifically for male or female pelvic areas;
- 2D FSE+DIXON; obtaining four sets of contrast images in one scan, insensitive to magnetic field inhomogeneity, usable for fat suppression in pelvic areas, etc.;
- Dual-echo 2D FSE, achieving PD and T2-weighted images in a single acquisition;
- Multi-b-value diffusion imaging, with up to 16 configurable b values;
- Dynamic curve analysis by dynamic analysis software for positive enhancement, obtaining positive enhancement parameter maps;

- Non-contrast renal artery imaging based on 3D bSSFP, achieving non-enhanced renal artery imaging, useful for imaging renal artery stenosis, etc.; CEMRA, using bolus injection of contrast agent to significantly shorten blood T1 values, shorter than other tissues, using ultra-fast T1WI for imaging;
- 2D PC for quantitative analysis of blood flow;
- FSE-based body vascular plaque imaging.

## 2.2 Standard Sequences

### 2.2.1 Spin Echo (SE)

Spin Echo (SE) sequence is a classical MRI sequence, which is widely applied in clinic and mainly for T1WI. SE sequence is advantaged in providing high signal-to-noise ratio of image and good tissue contrast. It is less sensitive to inhomogeneous magnetic field and is not prone to susceptibility artifacts. SE sequence can be utilized for imaging of all body parts, usually for conventional T1WI and enhanced scanning of head, spine, and joints, etc.

SE sequence is composed of a  $90^\circ$  RF pulse followed by a  $180^\circ$  repolarization pulse. After a  $90^\circ$  RF pulse is emitted along the X direction, the magnetization vector in the Z direction is flipped to the XY plane. After the  $90^\circ$  pulse is closed, the magnetization vector will undergo transverse relaxation and the transverse magnetization vector will gradually decay. If a  $180^\circ$  refocusing pulse is applied in the Y direction immediately after the  $90^\circ$  pulse, the obtained image contrast will almost eliminate the influence of tissue T2 relaxation. If the  $180^\circ$  repolarization pulse is applied after waiting for a suitable period of time, the residual transverse magnetization vector of different tissues will appear different due to the difference of transverse relaxation velocity in order that T2 contrast information can be obtained.

### 2.2.2 Fast Spin Echo (FSE)

Fast Spin Echo (FSE) sequence is the technique of applying a series of refocusing pulses after one RF pulse excitation, and acquiring multiple echoes. The echo collected after each RF pulse excitation constitutes an echo train, and the number of echoes in the echo train is the echo train length (ETL). By applying different phase coding gradients before each signal acquisition, these acquired echoes can be filled in different positions in k-space. Therefore, the scanning speed of FSE sequence is faster than that of SE sequence. The susceptibility sensitive artifact of FSE sequence is not obvious because the refocusing pulse can eliminate the influence of the main magnetic field's inhomogeneity.

By adjusting the scanning parameters of FSE sequence, T1WI, T2WI and proton-density-weighted images can be obtained. Because of its characteristics of rapid imaging, FSE is widely used in clinic. When a shorter echo train is selected, FSE sequence can obtain T1 weighting, which is shorter than SE sequence's acquisition time. It is often used to display anatomic structures such as the spine, large joints, soft tissues, etc. When a longer echo train is selected, FSE sequence is often used for PD and T2 weighting, and the scanning speed is significantly faster than SE, which is mainly used for the scanning of the nervous system, joints, whole body, etc.

FSE sequence supports flow compensation technique to reduce signal loss and pulsation artifacts caused by flow. It also supports parallel acquisition and reconstruction to speed up imaging. It supports breath hold multi-sectional scanning, which can be used for multiple breath hold scans of the abdomen to achieve full abdominal coverage scanning. FSE sequence supports a variety of fat suppression technique and provides excellent fat suppression effect. It supports physiological signal triggering: it can use respiratory signals to trigger scanning during abdominal scans in order to suppress motion artifacts. It supports 3D scanning and can be used for high-resolution inner ear imaging.

### 2.2.3 Single Shot Fast Spin Echo (SSFSE)

Single Shot Fast Spin Echo (SSFSE) sequence has a long echo train. After one excitation, all information needed to fill  $k$ -space image can be obtained, and the scanning speed is faster. Because the TR's length is actually infinite, it is only used for T2WI image acquisition.

Due to its long echo train, in order to reduce the blurring effect in the image caused by T2 relaxation, the acquisition of the echo train needs to be completed in as short time as possible. SSFSE is realized by shortening the echo interval and techniques such as fast acquisition and partial Fourier. It supports radial plane planning and can be used for multi-directional MRCP (Magnetic Resonance Cholangiopancreatography) thick film imaging.

Compared with FSE sequence, SSFSE sequence has a significantly shorter scanning time and can be used for T2WI of chest and abdomen breath hold scans; SSFSE sequence can also be used to obtain high-resolution water imaging of long T2 tissues, such as MRCP, Magnetic Resonance Urography (MRU), Magnetic Resonance Myelography (MRM), etc.; Brain ultra-fast T2 imaging (applied to patients who cannot actively cooperate with the scan).

### 2.2.4 3D Variable Refocus Flip Angle Isovoxel Imaging (3D ISO)

Based on 3D FSE sequence, the 3D ISO technique is used to reduce image blur caused by T2 attenuation effect by attenuation process controls of the echo train. It can be applied to the scanning of ultra-long echo train and to optimize the acquisition sequence in  $k$ -space, which can greatly reduce the scanning time with satisfactory signal-to-noise ratio and resolution of 3D acquisition guaranteed. By optimizing the calculation of RF pulses, the energy deposition in the human body can be improved, and the RF absorbed energy (SAR) can be greatly reduced to ensure the safety of patient during the examination.

3D ISO sequence is widely applied in clinic. It can be used for high-resolution isotropic scanning of joints, nervous system etc., as well as water imaging whole body scan. It can improve the imaging resolution and achieve outstanding energy control.

### 2.2.5 Dual Echo Fast Spin Echo Sequence (DualEcho)

Based on the 2D FSE sequence, DualEcho uses two  $180^\circ$  pulses after a  $90^\circ$  radiofrequency pulse, with the same phase encoding, generating a short TE echo and a long TE echo. In long TR sequences, proton density-weighted

and T2-weighted signals can be obtained simultaneously in one scan. This sequence is commonly used for imaging muscles, bones, and other areas, improving imaging efficiency.

### 2.2.6 Inversion Recovery Spin Echo (IR SE)

Using a  $180^\circ$  RF pulse to excite the tissue can deflect the macroscopic longitudinal magnetization vector of the tissue by  $180^\circ$ , that is, to the direction opposite to the main magnetic field, so it is also called a reversal pulse. IRSE sequence is to apply a  $180^\circ$  inversion pre-pulse before SE sequence to increase the longitudinal relaxation difference among tissues, which can provide better contrast in clinic. The time interval between  $180^\circ$  inversion pulse and  $90^\circ$  excitation pulse is defined as Inversion Time (TI).

IRSE sequence provides the best T1 contrast, which is significantly higher than that of SE. It has low sensitivity to general magnetic field inhomogeneity and off-center scanning caused magnetic field inhomogeneity. Because only one echo is collected during one inversion, and the scanning time is long, it is mainly used to increase T1 gray-white matter contrast in clinic.

### 2.2.7 Inversion Recovery Fast Spin Echo (IR FSE)

IR FSE is composed of a  $180^\circ$  pre-pulse followed by an FSE sequence. Compared with the IR sequence, the imaging speed can be greatly accelerated due to the presence of echo train. By adjusting TI time, the water signal or fat signal can be selectively suppressed.

Clinical applications include:

- STIR (Short Time Inversion Recovery sequence) : because the longitudinal relaxation velocity of adipose tissue is short, STIR is widely used in fat suppression scanning of T2WI. It has low sensitivity to magnetic field inhomogeneity and is suitable for fat suppression in a large range or in the center;
- FLAIR (Fluid Attenuated Inversion Recovery) : a water suppression sequence. In clinical application, because both lesions with slightly high signal and the ones with high signal are often obscured by the cerebrospinal fluid signal with higher signal. In this case, if the cerebrospinal fluid signal can be suppressed in T2WI, the lesions can be fully revealed. FLAIR can inhibit the cerebrospinal fluid signal and are widely used in brain scanning; FLAIR can also achieve T1WI, which can show the T1 gray-white matter contrast more effectively;
- Black blood inversion recovery technique to inhibit blood flow signals.

### 2.2.8 Spoiled Gradient Recalled Echo (SPGR)

SPGR sequence uses the echo signal generated by gradient field inversion for imaging. The gradient echo signal reaches steady state after a period of transition time. Generally, the acquired steady-state gradient echo signal originates from the longitudinal and transverse steady-state magnetization vectors. RF phase spoiling technique can be applied to SPGR sequence to disperse the transverse steady-state magnetic direction vectors to zero, so that the size of the collected gradient echo signal only depends on the longitudinal magnetization vectors in order to achieve T1 contrast. Compared with SE sequence, the gradient echo sequence is more sensitive to magnetic field inhomogeneity, and

it can better reflect local susceptibility differences and achieve T2\* contrast. SPGR can be used for multi-echo acquisition to generate in-phase and out-phase images. SPGR supports parallel acquisition and reconstruction technique for imaging acceleration.

SPGR sequence is widely used in clinic, mainly for T1WI of the head, chest, abdomen, pelvic cavity, etc. T2\*WI imaging is mainly used for cerebral hematoma and articular cartilage imaging. It can be used for dual-echo imaging of abdomen and pelvis.

### 2.2.9 Fast Gradient Recalled Echo (FGRE)

FGRE sequence is one of the fast phase spoiling gradient echo sequences. Contrast is controlled by using magnetization preparation pulses, i.e. inversion recovery pulses. After each inversion recovery pulse, all coding lines in k-space will be acquired, and the imaging time will be greatly reduced by combining partial Fourier, parallel acquisition and so on with it. The application of RF phase spoiling technique makes the images obtained by FGRE obtain better T1 weighting.

FGRE is mainly used for 2D T1WI of the abdomen and pelvis, mainly for patients who cannot hold their breath as required.

T1WI of head 3D provides excellent contrast, and its gray-white matter contrast is better than the T1WI sequence without inversion recovery pulse.

### 2.2.10 Steady State Free Precession Gradient Echo (SSFP)

As a basic gradient echo sequence, SSFP applies a balanced gradient in the direction of frequency coding and phase coding to make the transverse magnetization signal reach a steady state. SSFP is mainly used for reconstruction and examination of large joint disease in clinical application.

### 2.2.11 Balanced Steady-State Free Precession Gradient Echo (bSSFP)

Ordinary steady-state free precession gradient echo technologies only consider the influence of the phase coded gradient field on the residual transverse magnetization signal, while bSSFP is a high-speed and high signal-to-noise ratio sequence. With sequence design in the three aspects including slice, phase, and coding, it can ensure that the transverse and longitudinal magnetization signals reach the steady state at the same time without losing the signal strength.

bSSFP is mostly used to obtain T2/T1 contrast of tissues, which is suitable to be applied in the whole body and is widely applied in head, blood vessels, abdomen, joint scans and so on. Its wide application is because of its advantages of fast speed and high signal-to-noise ratio, it is especially suitable for scanning the parts that are prone to being affected by motions. In addition, its tissue signal intensity determined by the T2/T1 ratio of the tissue, which can make the water signal prominent in the image, while other signals, such as muscle signals, will be inhibited, so it is widely used to make the contrast between liquid and soft tissue. It can achieve excellent imaging of blood vessels, pancreaticobiliary tract, urinary tract, gastrointestinal tract and so on with the absence of contrast agent.

## 2.2.12 Volumetric Acquisition with Lipid Suppression for Ultrafast Enhanced Imaging (VALUE)

VALUE is one of the fast phase spoiling gradient echo sequence. The TR and TE of this sequence are short, and the acquisition time is shortened by combining parallel acquisition, partial Fourier, interslice interpolation and other accelerated imaging technologies. This sequence applies the fast lipid suppression pulse technique, which can continuously collect multiple k-space coding lines after a lipid suppression pulse, further shortening the acquisition time. VALUE can be used for T1WI 3D fast imaging, commonly used for dynamic contrast-enhanced scanning of the whole body, and can also be used for high-resolution images of joint regions.

For scanning of body parts (such as breast and joints) without breath holds, its TR can be slightly longer, and 3D images with high signal-to-noise ratio and high resolution can be obtained. For dynamic contrast-enhanced scanning of abdominal organs (such as liver and gallbladder) that need breath holds, its TR is short, and multiphase dynamic contrast-enhanced scanning can be achieved through multiple breath holds scans.

## 2.2.13 Contrast Enhanced Magnetic Resonance Angiograph (CEMRA)

Contrast Enhanced Magnetic Resonance Angiography (CEMRA) is based on the T1WI fast phase spoiling gradient echo sequence. After injecting the contrast agent, the T1 value of blood is greatly reduced, making its T1 value significantly shorter than that of human normal tissue, and then CEMRA sequence can be used for vascular imaging.

Because the contrast of blood vessels and other tissues on the image is mainly caused by injecting contrast agent, an accurate control of the time when the contrast agent reaches the vessel of interest will directly affect the imaging result. Therefore, the Bolus tracking protocol is usually used to track the arriving time of contrast agent in vessels. Short TE and short TR are generally used in combination with the subtraction operation of reconstruction. CEMRA supports automatic subtraction.

## 2.2.14 Time of Flight Gradient Echo (2D & 3D TOF)

Time of Flight (TOF) Magnetic Resonance Angiography (MRA) mainly uses the blood flowing into the imaging slice to enhance the intensity of the blood signal compared to the static tissue. This mechanism of enhancing the blood signal is called Flow-Related Enhancement (FRE). When TR is relatively short, by repeatedly exciting the imaging slice, the static tissue is partially saturated, and its signal is inhibited, while the fresh blood flowing into the imaging slice is less affected by RF pulses and less saturated, resulting in a strong signal. In the image, it shows a bright blood signal, while the static tissue is dark due to saturation.

TOF sequences are generally realized using short TR steady-state incoherent gradient echo sequences. In order to eliminate the signal loss caused by flow, a flow compensation gradient will be used. This sequence combined with TONE technique makes vascular imaging more uniform. When used, 3D display is generally carried out with MIP technique to make the vascular appear clearer and more detailed and it is mainly used for head and neck scans.

### 2.2.15 Phase Contrast (PC)

Phase Contrast (PC) is a method that uses the phase change of transverse magnetization vector generated by blood flow to inhibit background tissue and highlight blood flows. On the basis of a short TR gradient echo sequence, PC applies bipolar gradient in one or more selected flow coding directions for flow coding, resulting in a phase change that is linearly related to the flow rate. The stationary tissue phase is completely offset, while the phase change generated by flowing blood is retained, and this difference forms phase contrast. The speed coding (VENC) in PC sequence can be freely adjusted in multiple directions. PC's background tissue inhibition is good, which is helpful for the display of small blood vessels and slow blood flow. In clinical application, PC can be used for intracranial artery and vein imaging.

### 2.2.16 Multi-Echo Data Image Combination (MEDIC)

After a small-angle RF pulse excitation, the sequence uses multiple switches of the readout gradient field to collect multiple gradient echoes, all of which adopt the same phase coding to compress acquired data to the same phase coding line in k-space. This method is equivalent to the approach of collecting the gradient echo sequence of a single echo for multiple repetitions. Finally, the reconstructed images of all echoes are combined into one image, and the signal-to-noise ratio can be greatly improved. The sequence applies flow compensation gradients in three directions to eliminate the influence of flow effect.

Clinically, MEDIC is mainly used for articular cartilage imaging, such as T2\*WI of knee. The joint fluid shows a higher signal on this sequence, while the articular cartilage shows a slightly high signal, which makes it easier to show the defects on the joint surface. T2\*WI of the cervical spine can provide a better display of the intervertebral disc and gray-white matter of the spinal cord. 3D merge T2\*WI can clearly show the spinal nerve root.

### 2.2.17 Gradient Recalled Echo Echo Planar Imaging (GRE EPI)

Echo Planar Imaging (EPI) is developed on the basis of gradient echo. GRE EPI is a member of the echo planar sequence family. By continuously applying alternating positive-negative frequency encoding gradients and adopting short phase encoding gradients, all data required in k-space can be collected by one RF pulse excitation. The echo of EPI sequence is generated by the continuous forward and reverse switching of frequency encoding gradient, resulting in a zigzag filling pattern in k-space. This k-space filling trajectory can be accurately realized only when the phase encoding gradient and the frequency encoding gradient work together. The phase encoding gradient needs to be applied after the previous echo acquisition and before the next echo acquisition. The MR signal collected by the GRE EPI technique itself also belongs to the gradient echo, generating the T2\* weighting, which is mostly used for MRI First-Pass Perfusion-Weighted Imaging with Contrast Agent (Perfusion) as well as Brain functional imaging based on Blood Oxygen Level Dependent (BOLD) effect.

### 2.2.18 Spin Echo Echo Planar Imaging (SE EPI)

SE EPI is an echo planar sequence based on SE sequence to reduce the influence of magnetic field

inhomogeneity on the image. By continuous correction, the anti-alternating frequency encoding gradient and the short phase encoding gradient are used to collect all the data needed in k-space with one RF pulse excitation. SE EPI adopts the single-shot excitation, which eliminates the influence of T1 relaxation on image contrast. It is generally used as a clinical fast scan of T2WI. It is suitable for abdominal breath hold scanning. The imaging speed is extremely fast. Even without breath hold, there is no obvious respiratory motion artifact. It is also suitable for ultra-fast T2WI of the brain and scanning of various parts of patients who cannot cooperate with the examination.

## **2.3 Standard Scanning Techniques**

### **2.3.1 Fast Acquisition Techniques**

#### **2.3.1.1 Partial Fourier**

By utilizing the complex conjugate symmetry of the k-space in the phase direction, theoretically, it is only required to acquire and fill half of the phase encoding lines of the k-space to reconstruct the image. Since the phase coding lines in and near the center of k-space determine the contrast of the image, a little more than half of the phase coding lines in k-space need to be collected in the actual scanning, and the rest are filled with the symmetry principle.

If the k-space is slightly more than 50%, the total acquisition time will be shortened accordingly, and the signal-to-noise ratio of the image will be slightly reduced.

#### **2.3.1.2 Partial Read Out**

K-space also has conjugate symmetry in the direction of frequency coding. Theoretically, only half of the echo need to be collected to reconstruct the image according to the symmetry principle. In the actual scanning, a little more than half of each echo needs to be collected to reconstruct images with higher quality. Partial echo technique can only be used for sequences without the echo train. By shortening TE, the acquisition time can be shortened or the number of acquisition slices can be increased.

#### **2.3.1.3 Rectangular FOV**

In clinical imaging, the cross-sections of some examined body parts are not square: for example, the cross-section of the abdomen, the left and right widths are significantly greater than the front and rear heights. Therefore, the acquisition of some phase coding lines in the front and rear direction is a waste of scanning. If to replace square one for acquisition by a rectangular FOV, to shorten the number of phase encoding step, the phase encoding lines in k-space will become sparse; also reduce the length on the phase coding direction in image reconstruction, FOV will be presented as a rectangle, which can reduce the acquisition time. This technique is widely used in the scanning of various parts, and is most typical in the application of oblate human body parts, such as abdominal and pelvic transverse sections, spinal sagittal position, etc.

### **2.3.1.4 Parallel Imaging (PI)**

PI (Parallel Imaging) is an ultra-fast MRI acceleration technique combined with phased array coil. It is widely used in the accelerated acquisition of various sequences, and can obtain higher temporal and spatial resolution within a given scanning time. According to the different phased array used, the image acquisition speed (acceleration factor) can be increased by 1~4 times.

The principle of PI technique is mainly to use the data collected by the multichannel receiving coil to reduce the number of k-space coding acquisitions, so that the sequence scanning time is shortened by double to achieve fast scanning. At the same time, the prior knowledge is used to fill the k-space data in the reconstruction to complete the image reconstruction.

The application of PI technique can speed up the conventional clinical scans of body parts and improve patients' scanning efficiency. Due to the faster acquisition speed, the spatial resolution can be improved and the range of 3D acquisition imaging can be increased when acquisition time remains unchanged. For EPI, it can shorten the echo train length, improve image quality, and reduce magnetic sensitive artifacts.

### **2.3.1.5 Dual-directional Accelerated Imaging (GRAPPA)**

GRAPPA (GeneRalized Autocalibrating Partially Parallel Acquisitions) is an extension of parallel imaging acceleration technique for 3D imaging. When using a multichannel receiving coil, data acquisition acceleration in two encoding directions is realized at the same time. Without losing the spatial resolution and scanning range, it can greatly shorten the 3D imaging time.

### **2.3.1.6 Ultra-Fast Imaging Based on Compressive Sensing (pSENSE)**

Compressed Sensing (CS) is an MRI acceleration technique different from parallel imaging. By taking advantage of the sparsity of imaging signals, it can recover high-quality images from data far less than the traditional sampling requirements. WDM's pSENSE (power SENSE) technique innovatively combines non-coherent undersampling in compressed sensing with parallel acquisition SENSE, greatly reducing the number of k-space coding steps, shortening the sequence scanning time by double, and achieving the purpose of fast scanning. At the same time, sparse transformation and nonlinear iterative reconstruction are applied to fill k-space data and complete image reconstruction. The application of pSENSE technique can speed up the 3D imaging scans in clinical application, such as TOF MRA, SWI and CEMRA, etc. and quicken the flow of patients. Due to the faster scanning speed, the spatial resolution can be improved or the imaging range of 3D acquisition can be increased with the condition of acquisition time unchanged.

### **2.3.1.7 Elliptical Acquisition**

The central information in the k-space has the most significant impact on image contrast and signal-to-noise ratio. In conventional imaging, the k-space is fully sampled, while in elliptical acquisition, priority is given to filling the central information in the k-space. Elliptical acquisition technique is widely used in vascular imaging, which can effectively shorten the scanning time, obtain high contrast vascular imaging,

and reduce motion artifacts.

## 2.3.2 Fat Suppression Techniques

### 2.3.2.1 Frequency Selective Fat Saturation Method (FatSat)

Based on WDM's industry-leading magnetic field homogeneity and the hardware of the special phased array coil, FatSat technique can selectively saturate the fat peak in the spectrum by using the chemical shift difference between fat and water to achieve the purpose of fat suppression.

Chemical shift effect refers to the difference of 3.5ppm between the precession frequencies of protons and water molecules in fat in a magnetic field. If pre-pulses consistent with the fat precession frequency are applied continuously before the excitation pulses of the imaging sequence, the fat signal can be selectively saturated.

The FatSat method can achieve good fat suppression effect in high field, and has high requirements for the uniformity of  $B_0$  field and RF field. It can be used in a variety of weighted sequences.

### 2.3.2.2 Accurate Selective Excitation with Preservation of Inversion Recovery (ASPIR)

ASPIR technique can be understood as a combination of the frequency selective FatSat technique and the inversion recovery technique. Frequency selective fat saturation adiabatic pulses were used, and the inversion time was automatically calculated to maximally suppress the fat signal. ASPIR is not sensitive to the nonuniformity of RF field, and has satisfactory effect and consistency of fat suppression.

Clinically, ASPIR is widely used for fat suppression in spine, abdomen, breast and other parts with high signal-to-noise ratio.

### 2.3.2.3 Spectral Excitation

Spectrum-specific excitation technique usually adopts binomial pulses of frequency and space selection, i.e., the combination of multiple pulses with different deflection angles and directions. When the system frequency selects the water peak frequency to make water reach the maximum transverse magnetization vector, and the transverse magnetization vector of fat is zero, only water signals are collected at this time, therefore Spectral Excitation is also known as water excitation technique. When the system frequency selects the fat peak frequency, only fat will be excited. Spectral Excitation technique is sensitive to  $B_0$  inhomogeneity and is mostly used in body parts with uniform  $B_0$  field.

### 2.3.2.4 STIR (Short Time Inversion Recovery)

STIR (Short Time Inversion Recovery) has been introduced in Standard Scan Sequences. It is realized by IR sequence and is widely used. While it is not demanding in magnetic field homogeneity and RF field uniformity, it can obtain satisfactory fat suppression effect in large FOV and off-center scanning.

### 2.3.2.5 Echo Planar Imaging Based on Inversion Recovery (IR EPI)

Similar to STIR technique, fat suppression can be achieved by applying inversion recovery pulse on the basis of EPI sequence. The process is to apply inversion recovery pulse followed by a certain inversion time (TI), to apply 90° pulse, and then to conduct EPI acquisition.

### 2.3.2.6 Water-Fat Separation Imaging (DIXION, fDIXION)

Human MRI signals mainly come from two components: water and fat. Due to their different chemical structures at the molecular level, the precession frequency of hydrogen protons in water molecules is slightly faster than those in fat molecules, with a difference of about 3.5ppm. According to the frequency difference between water and fat, different water fat phase differences can be obtained at different echo times. In particular, when the water-fat phase differences are 0° and 180°, they are called in-phase and out-phase, respectively.

DIXION's technique is based on FSE sequence and it adopts two-point acquisition method to collect data with different water-fat phase differences at different echo times. Water image, fat image, in-phase and out-phase images are obtained by calculation. The two-point method uses two TRs to collect water and fat in-phase and out-of-phase images respectively, which has a high signal-to-noise ratio and it is not easy to be affected by field inhomogeneity, while the imaging time is long. fDIXION adopts the three-point acquisition method to collect two out-phase images and one in-phase image in one TR, which enables a higher imaging efficiency. The two out-phase images can be verified to the in-phase image for water-fat separation, and to each other. The separation result is better, while the image signal-to-noise ratio is lower than that of the two-point method.

DIXION and fDIXION's fat suppression almost cannot be affected by B<sub>0</sub> and B<sub>1</sub> uniformity, with a high fat suppression accuracy and uniformity. DIXION and fDIXION can also obtain excellent uniform fat suppression effect for maxillofacial region, cervical spine, thoracic vertebrae, large FOV (such as abdominal COR and spinal SAG), legs, patella, heels and other parts with relatively uneven B<sub>0</sub>, as well as abdomen, pelvic region, breast and other body parts with extremely uneven B<sub>1</sub>; and they can be used as T1WI, T2WI and PD weighted imaging.

### 2.3.3 Multi-Slice Multi-Angle Planning

The same scanning sequence carries out multiple-slice acquisition in multiple directions. Each slice group can set slice orientation independently, and each slice group can contain multiple slices. It is often used for positioning images, scan positioning of three planar imaging.

SPGR gradient echo sequence is often used to quickly obtain multi-level and multi-angle images. By observing the images on multiple planes (three planes, etc.) in a combinative approach, operators can speed up the positioning procedure and improve the planning accuracy.

### 2.3.4 GRE In-Phase and Out-Phase

The precession frequency of hydrogen protons in water molecules is slightly faster than those in fat

molecules. After RF excitation, the transverse magnetization vectors of fat and water are in the same phase. After a few milliseconds, the protons in water molecules and those in fat are in opposite phases, and their macroscopic transverse magnetization vectors cancel each other. Then the MR signal collected at this time is equivalent to the difference between the signals of these two components; this image is therefore called inverse phase image. After a few milliseconds, the proton phase in the water molecule is in phase with that in the fat. At this time, the collected signals are the sum of the two components' signals.

In-phase and out-phase gradient echo technique can generate in-phase and out-phase images by one acquisition, improving the diagnostic accuracy. Clinically, it is generally used for the diagnosis and differentiation of fatty liver and adrenal lesions.

## 2.3.5 Spatial Saturation Techniques

### 2.3.5.1 Regional Saturation Band

The saturation pulse and gradient dispersion techniques are used to selectively excite the selected region, so that the region is saturated without generating signals. The free saturation band can be placed anywhere in or out of the FOV, and is mainly used to remove the effects of respiratory movement, vascular pulsation, and swallowing movements, etc. on imaging.

### 2.3.5.2 Parallel Saturation Band

Similar to the free saturation band, the unwanted signal and the redundant signal that may affect the imaging quality are saturated and removed by using this technique. During the scanning process, the band is automatically placed in a position parallel to the imaging film slice for the convenience of doctors. It is mainly used to saturate the impact of inflow blood on imaging.

### 2.3.5.3 Tracking Saturation Band

Tracking Saturation Band refers to that the saturation zone will always follow the position of the scanning slice. It is mainly used for TOF (Time of Flight) vascular imaging to eliminate the interference of arteries or veins on the imaging.

### 2.3.5.4 Graphical and Interactive Saturation Band Planning

The position of the saturation band is clearly displayed on GUI, which can be controlled by dragging the mouse cursor on GUI. The thickness and interval of the saturation band can be altered in a visualization approach.

## 2.3.6 Conventional Artifact Suppression Techniques

### 2.3.6.1 Flow Compensation

By applying flow compensation gradient, the phase error caused by flow and the flow artifacts can be

reduced. In clinic, flow compensation can reduce the signals brought by different flow rates of blood, cerebrospinal fluids and other clinically undesirable flows, improving the image quality.

### **2.3.6.2 Respiratory Trigger**

External wireless connection sensors can be used to monitor the patient's breathing during the scanning of the chest, abdomen, and pelvis, and scanning control can be realized, so that each scan falls in the same expiratory phase position, reducing respiratory motion artifacts. Continuous respiratory signals can be displayed on the scanning UI and the dual-touch screen in the scanning room, reflecting the movement of the abdominal cavity when the patient breathes.

### **2.3.6.3 Multi-breath Hold Scanning**

With continuous and multiple breath holds, the chest, abdomen and pelvis can be scanned to eliminate the influence of breathing motions on the image, so that these applications are not limited by the scanning range and the number of scanning slices.

### **2.3.6.4 Average Mode**

Average Mode includes both long-term averaging and short-term averaging modes. By averaging the data collected for many times, the technique is mainly used to improve the signal-to-noise ratio of the image, and also can suppress the influence caused by motion to a certain extent.

## **2.3.7 Image Quality Fidelity Techniques**

### **2.3.7.1 Multi-Channel Combination**

Multi-channel combination techniques include SOS (Sum of Square) , CMC (Coil Map Combine) , TCMC (Two Coil Map Combine) and Adaptive (Adaptive Channel Combine).

The SOS method takes the amplitude size of each channel as the weight and merges it into the final amplitude image.

The CMC method calculates a Coil Sensitivity Map from the images of each coil channel. In the process of channel merging, then Coil Sensitivity Map is used to merge the images of each channel with weights, which can suppress the artifacts, noise and background signals in the low SNR region of each channel image, so as to obtain a multi-channel merged image with fewer artifacts and a cleaner background.

The TCMC method calculates to get two Coil Sensitivity Maps with different levels of smoothness for each coil channel based on the images from each coil channel, with different levels of smoothness. These coil sensitivity maps are then combined to form a Combined Coil Sensitivity Map, and weighted with the images from each channel, which provides better filtering effects on images contaminated by artifacts, achieving clearer multi-channel merging images.

The Adaptive method conduct the multi-channel data optimization analysis, in order to eliminate the influence from low-SNR regions on the optimal channel-merging weight. In the process of channel merging, Coil

Sensitivity Vector is used to estimate the coil relative sensitivity of each point in the image, which is then taken as the optimal merging weight under the current sensitivity distribution, obtaining the multi-channel merged image with the optimal SNR.

### **2.3.7.2 Geometry Correction**

In view of the nonlinearity of the gradient field edge, the pre-obtained system parameters are used to calibrate the image position distortion caused by the nonlinear factors of the gradient field in the reconstruction process, so that the deformed image edge can be restored, to overcome the image deformation in large FOV and restore the validity of the clinical image.

### **2.3.7.3 Uniformity Tune (uTune)**

The surface coil is physically non-uniform and its non-uniformity is hard to avoid, causing uneven brightness of the acquired image during scanning.

Advanced uTune calculates the corresponding brightness factor by collecting the sensitivity of each unit of the coil in advance, and correct the uniformity of the image by prior knowledge during scanning and reconstruction.

### **2.3.7.4 Image Filter**

Image Filter is a post-processing tool for the acquired clinical images, which can effectively improve the signal-to-noise ratio and contrast, increase the edge definition, improve the resolution of small lesions, and make the image neat and easier for diagnosis. It can also smooth images with lightly lower signal-to-noise ratios and enhance image edges that are too smooth to make them sharper.

### **2.3.7.5 Image Interpolation**

Image interpolation is an image post-processing method, which can increase or decrease the number of pixels for the image. By interpolating the image, it can make the image display clearer, show smooth tissue structure and sharp edges, make it easier to distinguish small details, and eliminate the sawtooth phenomenon caused by image magnification.

### **2.3.8 WDL Technology**

#### **2.3.8.1 Intelligent Localization (UltraScan)**

UltraScan intelligent localization is a deep learning-based MRI image localization method. By using a Unet segmentation model and corner detection, it rapidly and accurately identifies the cone of T2 sagittal images, annotates the cone, and automatically completes the axial multi-slice localization work, facilitating scan operators to quickly locate the scan, simplifying localization operations, improving work efficiency, and reducing the localization time.

#### **2.3.8.2 WDL Intelligent Denoising (WDL)**

WDL (Image DEnoising using Deep Learning) is a deep learning-based MRI image denoising method. By training a deep neural network, noise images are used as input, and the output is denoised images. A loss function is used to measure the error between the output image and “the gold standard”. Network parameters are updated through backpropagation to minimize errors, ultimately enabling the network to adaptively remove noise.

### **2.3.9 Phase Correction Technology**

#### **2.3.9.1 Fast Phase correction (FPC)**

FPC acquires non-phase-encoded data during prescanning to compensate for FSE sequence gradients and radio frequency, reducing phase direction image artifacts.

#### **2.3.9.2 Retrospective Phase Correction (RetroPC)**

RetroPC acquires non-phase-encoded data during prescanning, and compensates for phase using the prescan data during reconstruction to reduce phase direction image artifacts.

## 2.3.10 Other Standard Scanning Techniques

### 2.3.10.1 Sequential and Interleaved Slice Acquisition

Sequential and interleaved slice acquisition techniques are different strategies for the acquisition sequence of slices. When the sequential acquisition is applied, the acquisition slice is acquired from one side to the other side in sequence; when applying the interleaved acquisition, the acquisition is carried out at intervals between slices.

### 2.3.10.2 Variable Bandwidth

The pulse sequence sampling bandwidth is open to the operator for adjustment. The sampling bandwidth refers to the frequency of the echo signal read out by the system, which affects the echo acquisition time.

### 2.3.10.3 Adjustable Receiving Gain

The gain (magnification) of the collected signal can be adjusted.

### 2.3.10.4 Frequency Offset

The acquisition scanning frequency offset can be adjusted automatically or manually.

### 2.3.10.5 Negative Gap

The slice spacing can be set to negative, i.e., overlap between adjacent slices is allowed, and the scanning area is covered in all directions, meanwhile assuring the signal-to-noise ratio and the resolution of on slice directions.

### 2.3.10.6 Graphic and Interactive Slice Planning

- The slice position, slice thickness, FOV and other parameters during positioning are visible;
- Different scanning slices can be created through UI;
- The number or thickness of slices can be increased by dragging and rotating the position of slices via cursor control on UI;
- In all positioning windows, the position of the image slice and the position of the saturation band can be observed at the same time.

### 2.3.10.7 Automatic Coil Selection

- Automatically identify and select coil units according to scanning coverage;
- Slice positioning interface coil visualization.

### **2.3.10.8 2D/3D Tools and Post-processing**

Load a 2D image, translate, flip, zoom, and rotate, etc.; or load 3D images, VRT, MIP, MPR, MinIP, SSD and other functions.

### **2.3.10.9 Silent Scanning (Mute)**

When the gradient system is switching rapidly, the rapidly changing current in the gradient coil will cut the magnetic induction line of the static magnetic field to produce a strong Loren magnetic force, causing the vibration of the gradient coil to generate huge noise. The noise of the gradient coil can be reduced by decreasing the switching rate of the gradient system, the current change rate in the coil and its Loren magnetic force. When the gradient switching rate is decreased, the echo time interval will be increased, then the scanning time will be increased, and the image quality will be reduced (blurring images). After the gradient switching rate is reduced, Mute technique optimizes the RF pulse and acquisition bandwidth to reduce the increase of echo time and scanning time caused by the decrease of gradient switching rate, to synchronously reduce noise and maintain image quality.

### **2.3.10.10 Oversampling**

By increasing the number of coding steps in the phase coding direction and increasing the size of the acquisition FOV in the phase direction, the winding artifact in the phase coding direction is reduced. The OS factor is the phase coding direction over acquisition factor, and the scanning time will increase with the increase of NPW. The size of the over acquisition factor can be adjusted according to the coil coverage.

## III. Advanced Application and Post-Processing

### 3.1 Motion Artifact Correction (TURBINE)

TURBINE technique uses a radial k-space filling method that is insensitive to motion, and uses rotary signal acquisition approach. Each acquisition is able to contain the central data of k-space. At the same level, the acquisition and collection are carried out several times, and the overlapping information is used to remove the impact of movement during each acquisition.

This technique can perform imaging with multiple directions and weights in multiple parts of the whole body, which can significantly reduce the magnetic sensitivity artifact and motion artifact of the image. For patients and children who cannot control their movements intentionally, TURBINE has a significantly better imaging result than any conventional artifact suppression technique.

### 3.2 “Black Blood” Imaging

The dual-inversion technique is employed, where a dual-inversion pulse is applied before signal acquisition. The first inversion pulse is a non-slice-selective  $180^\circ$  pulse, which flips all tissue signals. Subsequently, the second inversion pulse, a slice-selective  $180^\circ$  pulse, is applied. The signals from the selected slice undergo two  $180^\circ$  pulses, causing the magnetization vector to return to its original state. However, blood in a flowing state receives only the first non-slice-selective  $180^\circ$  pulse. When its longitudinal magnetization vector crosses zero, the signal is acquired, resulting in blood signal suppression effect, thus forming "black blood."

Black blood imaging technique can be used to suppress blood signals, eliminating vascular pulsation artifacts. It is employed in cardiac MRI to enhance the contrast between the blood pool and myocardial tissue, and for vascular wall imaging, etc.

### 3.3 Brain Perfusion Imaging

After paramagnetic contrast agent was injected into the intravenous bolus, T2\*WI imaging was performed with GRE EPI sequence, and brain tissue signals are repeatedly acquired with high time resolution. After the contrast agent reaches the brain tissue, due to the existence of the blood-brain barrier, it can establish a number of small local magnetic fields inside and outside the capillaries, form a certain difference in magnetic sensitivity, accelerate the out-of-phase process of protons, and lead to the decline of tissue signal. The obtained time signal curve can be used to calculate the cerebral perfusion parameter map.

The main sequence features include:

- Based on GRE EPI sequence;
- Support PI technique;
- Support partial Fourier acquisition and reconstruction technique.

### 3.4 Arterial Spin Labeling (ASL)

Arterial Spin Labeling (ASL) is a non-invasive brain blood flow imaging technique. ASL is realized by magnetically labeling the protons in arterial blood before it enters the region of interest. Water molecules are used as endogenous tracers, and after a certain period of time, the labeled water molecules enter the target tissue along with the blood flow and diffuse into the extracellular space. Then energy transfer occurs between the labeled water molecules and the water molecules in the target tissue, saturating a portion of the water molecules in the tissue, meanwhile the MRI signal intensity of the tissue is reduced at a certain degree that is proportional to the blood flow in that tissue, and blood flow in the tissue can be calculated. ASL is based on 3D FSE sequence, with Pseudo-Continuous ASL (PCASL) as its labeling method.

### 3.5 Single Voxel Spectral Imaging (SVS MRS)

SVS MRS is used to study the metabolite content analysis in the human body. The single voxel spectrum scanning sequence includes two scanning techniques, SVS-PRESS and SVS-STEAM.

- Convenient scanning GUI on which voxels can be set to any size or position;
- Local 3D volume shimming can optimize the magnetic field homogeneity in the region of interest;
- With optimized water suppression technique, insensitive to  $B_1$  and T1, and ensuring the quality of metabolite spectrum;
- OVS (Outer Volume Suppression) technique: suppress metabolites in surrounding tissues by applying multiple saturation bands;
- Supports variable phase cycle;
- Automatic and manual interactive shimming.

### 3.6 Whole Spine Imaging (WSI)

WSI covers imaging of the entire spine, including the cervical, thoracic, lumbar, and sacral regions. These segments can be scanned in three sections, and the images are automatically stitched together to obtain a complete spine image. WSI can fully display pathologies within the spinal canal, spinal vertebrae, and surrounding ligaments. It provides a clear, intuitive, and comprehensive presentation of spine structures.

### 3.7 Pseudo PET Imaging

Pseudo PET Imaging technique provides a powerful tool for tumor examinations and follow-up diagnosis. This application includes a set of specialized imaging sequences as well as Post processing software. The imaging part includes a set of diffusion-weighted scanning protocols as well as T1 and T2WI scanning protocols. Slice shimming technique provides an ideal  $B_0$  field for each slice scanned. The frequency-selective fat suppression, inversion recovery, water excitation and other fat suppression techniques optimized specifically for DWI sequences fully suppress fat and ensure image quality. The

specifically optimized diffusion gradient ensures short scan time and high image signal-to-noise ratio at high B values (such as 1000). With the corresponding post-processing tools, DWI images can be panoramically reconstructed and can be displayed in multiple forms of MPR and MIP, or in a merge with anatomical images.

### 3.8 Susceptibility-Weighted Imaging (SWI)

Susceptibility Weighted Imaging (SWI) is an imaging technique with high sensitivity to subtle local magnetic field changes (such as deoxyhemoglobin, tissue iron deposition or calcification). It has become an important means to examine intracranial venous structures and iron deposition and other related diseases. Using the phase information in MR signals, SWI phase maps can distinguish paramagnetic substances (such as tissue iron deposition) from diamagnetic substances (such as calcification). Its main clinical applications include traumatic brain injuries, coagulation disorders or other hemorrhagic diseases, vascular malformations, cerebral infarction, tumors, neurodegenerative diseases with calcification or iron deposition, etc.

SWI uses 3D high-resolution, fully flow compensated gradient echo sequence for acquisition and thin-slice reconstruction. Through low-pass and high-pass filtering of the phase map and weighted multiplication to the amplitude image, SWI can fully show the intrinsic magnetic susceptibility characteristics differences among human tissues. The reconstruction of SWI mainly uses the phase map to weight the amplitude image, and then generates SWI image and MinIP image, which can be then combined with compressed sensing technique, to achieve rapid acquisition.

The software characteristics of SWI are:

- 3-direction flow compensation;
- Supports PI technique;
- Head-specific scanning protocol;
- Multiple calculation results display;
  - Amplitude diagram
  - Phase diagram
  - SWI diagram
- Sliding-window MinIP reconstruction of thin slice.

### 3.9 Diffusion-Weighted Imaging (DWI)

DWI sequence can detect the diffusion movement of water molecules in living tissues by applying a strong diffusion gradient, to obtain the characteristics and change information of tissue microstructure. B value is used to control the size of the diffusion gradient: the larger B value is set, the larger the diffusion gradient will be used. The ADC (Apparent Diffusion Coefficient) value of tissue can be calculated using the scanning results of multiple B values (at least two). In clinical applications, the high B-value for cranial imaging is often set at 800-1000 s/mm<sup>2</sup>, while for body imaging, it is commonly set at 800-1500 s/mm<sup>2</sup>.

In clinical practices, DWI is mainly used for the diagnosis of hyperacute and acute cerebral ischemia. Compared with conventional SE and FSE sequences, DWI can detect the signal abnormalities in the

ischemic area at an earlier stage. It can be used to assess post-stroke recovery and differentiate lesions with similar manifestations to cerebral infarction in clinic. DWI can also be employed for examinations in other body parts such as the abdomen, pelvis, and breast, etc.

### **3.10 3D Renal Angiography of Flow-In Steady-State Precession (3D RAFISP)**

3D RAFISP is developed based on 3D bSSFP. The 3D bSSFP sequence is designed to ensure that the gradient moments in all directions' zeroth order moments equal to 0 within the TR time, allowing the spin magnetization to achieve balance simultaneously in both the transverse and longitudinal directions. It can obtain free induction decay (FID) and spin echo signals at the same time, achieving high signal-to-noise ratio and enabling T2/T1 contrast of tissues. After applying CISS (Constructive Interference in Steady State) technology, it can be used for imaging small neural tissues, including displaying the anatomical structures of the inner ear and brachial plexus nerves. With the introduction of FLAIR (Fluid Attenuated Inversion Recovery) and single water excitation techniques, non-contrast renal artery imaging can be achieved. This technique can be used for the examination of renal artery stenosis and post-renal transplant evaluations.

### **3.11 Parametric Quantitative Imaging (MQT)**

MQT (MultiQuant Technique) is a brand-new MRI method, which can obtain a variety of contrast images used in clinic, such as T1WI, T2WI, FLAIR, STIR and so on by one scan, meanwhile getting the quantitative information of T1Map, T2Map and PD map. It generates contrast images according to the quantitative information of relaxation rate and proton density.

### **3.12 APD-Stitching**

APD-Stitching (advanced processing Stitching) is applicable to generate a complete mosaic image from the overlapping MR volume data and MIP projection data generated by the same examination.

- Display and store the complete synthetic image, composed of multiple overlapping images;
- such as spine and blood vessels;
- The spine and blood vessels were individually stitched using specialized algorithms;
- Multi segment images with different parameters (such as different FOV, resolution, matrix, slice thickness) can be stitched;
- Mosaic MIP images;
- The original image, detail image and mosaic image can be displayed in different formats;
- Supports imaging in different formats;
- Basic measurement.

### **3.13 ADP-Dynamic Evaluation**

ADP-Dynamic Evaluation aims at the data of the region of interest with dynamic changes. Each slice of the data

group contains multiple images that change over time. It allows users to observe and collect statistics of the region of interest, and the system will automatically display the signal intensity curve of the same cross-section at different time points in the region of interest.

- Time signal tracing for the selected ROI;
- Mirror image measurement of symmetrical structure;
- For the negative enhancement data, the following parameter maps can be obtained: negative enhancement integral, average enhancement time, peak time, signal enhancement ratio, maximum decline slope;
- For the positive enhancement data, the following parameter maps can be obtained: positive enhancement integral, peak time, signal enhancement ratio, maximum rise slope;
- Supports different formats of display and shooting;
- Basic measurement.

### 3.14 ADP-Brain Perfusion \*

Because the physiological or pathological activities of brain tissue are closely related to the local blood supply, it is of great significance for clinical diagnosis and treatment to obtain the local tissue blood perfusion and understand its hemodynamic and functional changes. In the diagnosis and treatment of sudden cerebrovascular accident, it is important to predict the size of the infarct region, evaluate the risk of adjacent region spread and design rescue therapy.

After intravenous injection of contrast agent, MRI cerebral perfusion scans the selected slices dynamically to obtain the time intensity curve of each tissue position; Then, according to different mathematical models, the relative Cerebral Blood Flow (CBF), relative Cerebral Blood Volume (rCBV), Mean Transit Time (MTT), Time To Peak (TTP) and other parameters are calculated, and the corresponding parameter maps were displayed. It can intuitively, efficiently and conveniently display the brain tissue perfusion changes.

- Time intensity curve analysis;
- Deconvolution mathematical model calculation;
- Automatic pre-processing: fully automatic motion correction, background removal;
- Arterial point selection: automatically select arterial point;
- Parameter map calculation: automatic calculation of relative CBF, rCBV, MTT, TTP parameter map and supports different color table schemes;
- ROI analysis: circular and rectangular ROI, symmetrical ROI analysis, different parameter value statistics;
- Save: users can screenshot the calculation results and save;
- Print: send the function image calculation result and original image to print;
- Report: organize calculation results, screenshots, statistical data, etc. to structured reports for editing and printing.

\* Advanced post-processing is required to obtain more parameter information.

### 3.15 ADP-MRS (SVS)

Single voxel spectrum advanced post-processing technique compares the fluctuation of a variety of specific metabolites with the normal concentration range, so that the pathophysiological changes can be diagnosed, especially in the early diagnosis of tumor and stroke. However, obtaining multiple parameters and quantitative analysis is a challenging and time-consuming work. The application of MR spectroscopy is able to intelligently, smoothly and comprehensively complete the noninvasive detection of metabolite levels in living tissues, and efficiently conduct quantitative analysis to determine the molecular composition and spatial distribution. By dynamically observing the changes of tissue metabolism, we can understand the progression of the disease and evaluate the therapeutic effect, providing important reference information for clinical treatment.

- Calculation and analysis of voxel spectrum data: automatically analyze the metabolites information such as NAA, CHO, Cr, Lac, etc.;
- Statistical analysis: automatically perform statistical analysis on the parameters of voxel compounds of interest;
- Save: calculation results can be saved as screenshots;
- Print: send the function image calculation result and original images to print;
- Report: organize calculation results, screenshots, statistical data, etc. to structured reports for editing and printing.

### 3.16 ADP-DTI \*

ADP-DTI (Advanced Processing Diffusion Tensor Imaging) is a neuroimaging analysis technique used to reconstruct and visualize nerve fascicles in the brain. Based on Diffusion Tensor Imaging (DTI) data, it calculates and tracks the diffusion direction of water molecules in nerve tissue to determine the direction and connection mode of nerve fascicles. This technique helps to study the structure and function of the brain, as well as understand the related problems in neurological diseases, brain injury and normal brain development. Nerve fascicles tracking is widely used in neuroscience, neurosurgery and clinical diagnosis.

- Parameter map calculation: after scanning, the Mean Diffusion Rate (MD) or Apparent Diffusion Coefficient (ADC) , Exponential Apparent Diffusion Coefficient (eADC) , Axial Diffusion Rate (AD) , Radial Diffusion Rate (RD) , Volume Ratio (VR) , Fractional Anisotropy Index (FA) , and Color FA Map are automatically calculated;
- Save: calculation results can be saved as screenshots;
- Print: send the function image calculation result and original images to print;
- Report: organize calculation results, screenshots, statistical data, etc. to structured reports for editing and printing.

\* Advanced post-processing is required to obtain more parameter information.

### 3.17 ADP-BOLD fMRI \*

ADP-BOLD fMRI (Advanced post-processing of brain functional imaging technique based on blood

oxygen level dependence) A neuroimaging technique used to study the functional activities of the brain. It is based on the change of oxygen content in blood, reflecting the activity level of brain regions in a specific task or state. When a certain region of the brain is activated, the oxygen consumption of brain tissue in that region increases, and deoxyhemoglobin increases accordingly. However, the blood perfusion volume in this region's brain tissue also increases at the same time, bringing more oxygenated hemoglobin. The final result is that the ratio of oxygenated hemoglobin to deoxyhemoglobin increases, so the signal intensity of brain tissue on T2WI or T2\*WI in that region increases. It is generally believed that when brain tissue is activated, its signal intensity increases, and when brain tissue activity is inhibited, its signal intensity decreases. BOLD contrast is obtained by comparing the changes of brain tissue signal intensity before and after receiving a certain stimulus or performing a certain task.

\* Advanced post-processing is required to obtain more parameter information.

### **3.18 ADP-T2 Mapping \***

T2 relaxation time is estimated by measuring the decay rate of MRI signal at different time points, which can provide important information about tissue properties, such as water distribution, fiber arrangement, and tissue lesions. By analyzing T2 values in different tissues, doctors can obtain more detailed information, which is helpful to understand health status and pathological changes of tissues.

\* Advanced post-processing is required to obtain more parameter information.

### **3.19 ADP-Cardiac \***

Cardiac function analyses mainly include left ventricular function analysis, right ventricular function analysis, overall heart function analysis, segmental function analysis, and systolic/diastolic analysis.

- Parameters: Ejection Fraction (EF) , Ejection Diastolic Volume (EDV) , End-Systolic Volume (ESV) , Stroke Volume (SV) , Cardiac Output (CO) , End Diastolic Myocardial Mass (EDM) , End Systolic Myocardial Mass (ESM) ;
- Save: users can screenshot the calculation results and save;
- Print: sending the calculated functional images and original images to print, etc.;
- Report: organizing the calculation results, screenshots, and statistical data to a structured report for users to edit and print.

T1 mapping directly acquires images without using contrast agents, and the relative changes in Intracellular Volume Fraction (ICV) and Extracellular Volume Fraction (ECV) can affect the T1's relaxation time of the myocardium.

- Automatically selecting the contours of the epicardium or endocardium;
- Manually selecting regions of interest for calculation;
- Editing the LRV connection points;
- Manually enable color map;
- Save: users can screenshot the calculation results and save;
- Print: sending the calculated functional images and original images to print, etc.;

- Report: organizing the calculation results, screenshots, and statistical data to a structured report for users to edit and print.

\* Advanced post-processing is required to obtain more parameter information.

## IV.Siting and Other Specifications

This section provides an overview of the siting requirements. More detailed information is available on request.

### Room Layouts

	System Configuration Recommended Values(mm)( WxDXH)
Magnet Room	7000×5000×3500
Equipment Room	3000×5000×3300
Control Room	3000×5000×3300

### Electrical Supply Requirements

Voltage (V)	380±10%
Frequency (Hz)	50/60±1
Recommended Distribution capacity (KVA)	200

### Environmental requirements

	Temperature (°C)	Relative Humidity(%)
Magnet Room	18-22	40-60
EquipmentRoom	18-22	40-60
Control Room	15-30	30-70