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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Magnetic resonance equipment for medical imaging –
Part 2: Classification criteria for pulse sequences

Appareils à résonance magnétique utilisés pour l'imagerie médicale –
Partie 2: Critères de classification pour les séquences d'impulsions

IEC 62464-2:2010

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MAGNETIC RESONANCE EQUIPMENT FOR MEDICAL IMAGING –

Part 2: Classification criteria for pulse sequences

FOREWORD

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International Standard IEC 62464-2 has been prepared by subcommittee 62B: Diagnostic imaging equipment, of IEC technical committee 62: Electrical equipment in medical practice.

The text of this standard is based on the following documents:

FDIS	Report on voting
62B/807/FDIS	62B/816/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

In this standard, the following print types are used:

– Requirements and definitions: roman type.
– *Test specifications: italic type.*
– Informative material appearing outside of tables, such as notes, examples and references: in smaller type. Normative text of tables is also in a smaller type.
– TERMS DEFINED IN CAUSE 3 OF THE GENERAL STANDARD, IN THIS PARTICULAR STANDARD OR AS NOTED: SMALL CAPITALS.

The verbal forms used in this standard conform to usage described in Annex H of the ISO/IEC Directives, Part 2. For the purposes of this standard, the auxiliary verb:

– "shall" means that compliance with a requirement or a test is mandatory for compliance with this standard;
– "should" means that compliance with a requirement or a test is recommended but is not mandatory for compliance with this standard;
– "may" is used to describe a permissible way to achieve compliance with a requirement or test.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

• reconfirmed,
• withdrawn,
• replaced by a revised edition, or
• amended.

INTRODUCTION

Presently the MANUFACTURERS of MR EQUIPMENT use names for PULSE SEQUENCES which are adopted from the literature (e.g. SPIN-ECHO) or are defined by the MANUFACTURER (e.g. FISP: fast imaging with steady state precession). In the absence of a classification standard for PULSE SEQUENCES, the MANUFACTURER-specific terminology complicates comparison of PULSE SEQUENCES.

The DICOM standard allows the inclusion of PULSE SEQUENCE information with digital MAGNETIC RESONANCE (MR) images. This information helps with the interpretation of images. However, the DICOM standard allows MANUFACTURER-specific terminology.

This International Standard specifies a concise MANUFACTURER-independent classification scheme for MR imaging PULSE SEQUENCES.

In terms of MR imaging, the PULSE SEQUENCE is a chronology of RF-pulses, switching of gradient fields and data acquisition with the intention to create one or more images. As the exact chronology determines the image contrast, image artefacts and other properties of the image, it is necessary to define a consistent and accurate PULSE SEQUENCE classification.

The proposed PULSE SEQUENCE classification notation could be implemented as a new DICOM tag in addition to the existing MANUFACTURER-specific PULSE SEQUENCE name. This would facilitate end users' access to this information. Implementation as a new tag would ensure backward compatibility.

MAGNETIC RESONANCE EQUIPMENT FOR MEDICAL IMAGING –

Part 2 – Classification criteria for pulse sequences

1 Scope

This International Standard specifies the description of PULSE SEQUENCES of MAGNETIC RESONANCE imaging.

NOTE The classification in this standard is suitable for:

– tender texts;
– image annotation;
– protocol definition;
– technical publications.

This International Standard does not apply to MAGNETIC RESONANCE spectroscopy. The classification does not focus on image contrast (T1, T2, proton density), as this is defined by PULSE SEQUENCE parameters (e.g. repetition time, echo time) and is not a property of the PULSE SEQUENCE alone. The PULSE SEQUENCE classification does not specify the K-SPACE acquisition scheme, reconstruction algorithm or post-processing.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60601-2-33:2010, *Medical electrical equipment – Part 2-33: Particular requirements for the basic safety and essential performance of magnetic resonance equipment for medical diagnosis*

IEC 60788:2004, *Medical electrical equipment – Glossary of defined terms*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60601-2-33:2010, IEC 60788:2004 and the following apply.

3.1
pulse sequence
chronology of radiofrequency-pulses, switching of magnetic field gradients, and data acquisition for the generation of one or more MAGNETIC RESONANCE images

NOTE The terms “imaging sequence” or “sequence” are sometimes used as synonyms for PULSE SEQUENCE.

3.2
transverse magnetisation
magnetisation component perpendicular to the direction of the static magnetic field

3.3
longitudinal magnetisation
magnetisation component parallel to the direction of the static magnetic field

3.4
k-space
mathematical space in which the Fourier transform of the image data is represented

NOTE This is partially or totally filled with the sampled measurement data.

3.5
spin-echo
SE
refocused TRANSVERSE MAGNETISATION arising at time *T* after an excitation RF pulse and an additional RF-pulse at time *T*/2

NOTE The excitation pulse is typically a 90° RF pulse, and the additional refocusing pulse is typically a 180° RF pulse. SE's can be refocused using a sequence of additional RF pulses.

3.6
gradient-echo
GR
refocused TRANSVERSE MAGNETISATION after a RF pulse using re-phasing magnetic field gradients

4 PULSE SEQUENCE classification

4.1 General

In an imaging PULSE SEQUENCE the LONGITUDINAL MAGNETISATION is partially or totally converted into TRANSVERSE MAGNETISATION via a radio-frequency (RF) excitation pulse. The TRANSVERSE MAGNETISATION is precessing with the Larmor frequency. The precessing TRANSVERSE MAGNETISATION induces the MR signal. For spatial encoding the precessing TRANSVERSE MAGNETISATION is phase-encoded with the help of gradients prior to the data acquisition, and frequency encoding is utilised during the data acquisition. The acquired signal is then stored in a so-called K-SPACE line of the raw data matrix.

The K-SPACE can be two- (2D) or three-(3D)-dimensional. There are several algorithms that allow reconstructing images from incomplete K-SPACE data sets (half or partial Fourier, parallel imaging techniques) – for the PULSE SEQUENCE classification these techniques are not considered.

PULSE SEQUENCES are categorised according to the following classifiers:

a) magnetisation modification (optional): modification(s) of the LONGITUDINAL MAGNETISATION or TRANSVERSE MAGNETISATION;
b) PULSE SEQUENCE type: SPIN-ECHO or GRADIENT-ECHO with the number repetitions (or shots) and the number of K-SPACE lines per RF excitation;
c) dimensionality of data acquisition: 2D or 3D;
d) echo number (optional): number of different echoes that are used to calculate separate images.

These classifiers are used in the following notation (without spaces):

<Magnetisation modification> – <Dimensionality of data acquisition> – <PULSE SEQUENCE type> – <Echo number>

4.2 PULSE SEQUENCE type

4.2.1 General

PULSE SEQUENCES create MR images whose signal behaviour is primarily determined by either a SPIN-ECHO (SE) or a GRADIENT-ECHO (GR). The PULSE SEQUENCE type is defined at the centre of the 2D or 3D K-SPACE: If the K-SPACE centre is acquired with a SPIN-ECHO, then the PULSE SEQUENCE is classified as a SPIN-ECHO PULSE SEQUENCE in this International Standard. If the centre of K-SPACE is not acquired with a SPIN-ECHO, then the PULSE SEQUENCE is classified as a GRADIENT-ECHO PULSE SEQUENCE in this International Standard.

A more precise classification the PULSE SEQUENCE type is achieved by providing information about the other K-SPACE lines. Therefore, the number of SPIN-ECHOES and GRADIENT-ECHOES per RF excitation are given.

Some image characteristics are sensitive to whether K-SPACE is totally acquired after a single RF excitation (single shot) or whether multiple RF excitations are required (multi-shot), so the number of RF excitations (shots) is also given.

4.2.2 Notation

For a SPIN-ECHO PULSE SEQUENCE the following notation is used:

<PULSE SEQUENCE type> : (SE_<Index1> GR_<Index2>)_<Index3>

For a GRADIENT-ECHO PULSE SEQUENCE the following notation is used:

<PULSE SEQUENCE type> : (GR_<Index1> SE_<Index2>)_<Index3>

Here, <Index1> and <Index2> denote the number of SPIN-ECHOES and GRADIENT-ECHOES, respectively. The values of <Index1> and <Index2> can be either integer numbers or formulas of the variables *N* and *M* using the signs “+”, “-“, “/”, and “x”. Here, *N* describes the total number of K-SPACE lines, and *M* is the number of K-SPACE lines per excitation. The part “GR_<Index2>“ or “SE_<Index2>“ is omitted, if <Index2> is zero.

<Index3> denotes the number of required RF excitations and is given either as an integer number or a formula of the variables *N* and *M* using the signs “+”, “-“, “/”, and “x”.

NOTE The sum of <Index1> and <Index2> is typically known as the echo train length, and <Index3> is often written as the number of shots.

4.3 Magnetisation modification

4.3.1 General

Optionally, the imaging characteristics of a PULSE SEQUENCE can be changed by adding gradients and RF pulses or by replacing parts of the PULSE SEQUENCE. These added pulses and gradients are used to prepare the magnetisation.

Different magnetisation modifications can be combined. The magnetisation modification is either acting primarily on the LONGITUDINAL MAGNETISATION or the TRANSVERSE MAGNETISATION, or is done during RF excitation.

For classification of the magnetisation modification, all parts of the PULSE SEQUENCES that have an additional influence on the image characteristics and that are not included in the classification of the PULSE SEQUENCE type are listed.

4.3.2 Notation

The magnetisation modification is written as a series of symbols as given in Table 1:

<Magnetisation modification> : <Symbol1> – <Symbol2> – ... – <SymbolN>

If no magnetisation modification is used, this classifier is omitted.

Table 1 – Magnetisation modification techniques

Symbol	Name	Physical principle
IR	Inversion recovery	Inversion of the LONGITUDINAL MAGNETISATION
SR	Saturation recovery	Saturation of the LONGITUDINAL MAGNETISATION
T2P	T2 preparation	Storage of a T2 contrast in the LONGITUDINAL MAGNETISATION using e.g. the pulses (90°)-(180°)-(-90°)
T2SP	T2* preparation	Storage of a T2* contrast in the LONGITUDINAL MAGNETISATION using e.g. the pulses (90°)-TE-(-90°)
SSAT	Spectral (chemical) saturation	Spectrally selective saturation of spins (e.g. fat, silicone, water)
SIR	Spectral (chemical) inversion	Spectrally selective inversion of spins (e.g. fat, silicone, water)
MTC	Magnetisation transfer contrast	Indirect saturation of the water signal using magnetisation transfer of spins bound to macromolecules
RSAT	(Regional) pre-saturation, tagging	Spatially selective saturation
RLAB	(Regional) labelling, spin labelling	Spatially selective excitation or inversion for tagging of moving spins
DE	Driven equilibrium	RF pulse at the end of the echo train for restoring the LONGITUDINAL MAGNETISATION
NS	Non-spatially selective excitation	RF pulse without slice selection gradient to excite all magnetisation in the volume of the transmitting RF coil
NRRF	Profiled (non-rectangular) RF pulse	RF excitation pulse with a dedicated, non-rectangular slice profile (e.g. to avoid saturation effects in TOF MR angiographies or for simultaneous excitation of two slices)
2DRF	2D selective RF pulse	RF pulse with a spatial selectivity in 2 dimensions
SSRF	Spatial-spectral RF pulse	Simultaneous spatially and spectrally selective excitation
DIFF	Diffusion weighting	Signal attenuation by additional gradients that induce a signal dephasing for diffusing spins
FLOWCn	Flow compensation [a]	Compensation of the n^{th} gradient moment to suppress flow related signal changes, where n is a positive integer
FLOWSn	Flow sensitisation	Amplification of the n^{th} gradient moment to enhance flow related signal changes, where n is a positive integer
T1R	Spin lock	T1ρ contrast by additional RF pulses
SPOIL	TRANSVERSE MAGNETISATION spoiling	Spoiling by gradient and/or radio frequency
AREF	Refocusing of all gradients	Refocusing of all gradients within one TR interval (balanced steady state free precession)
PREF	Partial refocusing of the gradients	Refocusing of some gradients within one TR interval
NREF	Refocusing of the gradients in the next TR interval	Refocusing of the gradients so that an echo is acquired in the next TR interval
OFFSET	Offset echo	Time offset between the SPIN ECHO and acquisition of the centre of K-SPACE

[a] If the classifier FLOWCn is not explicitly given, the PULSE SEQUENCE does not utilise flow compensation.

4.4 Dimensionality

4.4.1 General

With three-dimensional data acquisitions the spatial encoding of the signal from a volume is performed in all three dimensions, and data are sorted into a 3D K-SPACE. In two-dimensional data acquisitions encoding is performed only in the two in-plane dimensions of a selected slice, and a 2D K-SPACE is filled.

4.4.2 Notation

The dimensionality for a two-dimensional data acquisition is given by

<Dimensionality> : 2D

For a three-dimensional data acquisition the following notation is used:

<Dimensionality> : 3D

4.5 Echo number

4.5.1 General

Following an RF excitation, data can be acquired at different echo times, which leads to MR images with different contrasts. The number of reconstructed images with different contrasts is classified by the echo number.

4.5.2 Notation

The following notation is used for the echo number:

<Echo number> : E_ <Index>

<Index> is an integer number. If <Index> has a value of 1, the classifier is omitted.