T2-Weighted 3D MR Imaging of the Torso – First Clinical Experiences with SPACE

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Introduction:

MRT provides the best soft tissue contrast of all imaging methodologies. Based on the technological advances (e.g. coil technology, parallel imaging), magnetic resonance is also able to image large body areals during an examination. The acquisition of larger anatomical regions is frequently the basis for an improved understanding of the pathologies involved. Oncology proves this point better than most. In addition to accurate diagnoses of local tumor expansion, both rather demanding with respect to resolution and contrast, large anatomical regions are required to fully acquire the actual tumor expansion.

This is the only way to provide for an exact as well as clinically useful planning of individual treatment strategies.

Until now, high-speed acquisition of large volumes with high resolution was the domain of multi-slice computed tomography (MS CT). The newest generation of Spiral MS CTs allows for a quick realization of 3D data records in the submillimeter range. But it is the possibility of retrospective reconstruction of random image planes that provides for an additional decisive advantage when dealing with complex relationships between anatomical structures and pathological changes. Based on the poor soft tissue contrasting when compared to MRT, MS CT as such rarely suffices for an exact evaluation of the pathology involved.

Using the newest generation of Spiral MS CTs, isotropic 3D data records in the submillimeter range can be realized within a short period of time. However, there is also the possibility of retrospectively reconstructing random image planes that represents a decisive advantage for complex relationships between anatomical structures and pathological changes.

Based on the poor soft tissue contrast obtained as compared to MRT, MS CT is frequently not capable on its own to provide satisfactory statements in regard to exact evaluations of the pathology involved. As a result, the necessity of combining different examination modalities – unfortunately this also leads to a delay in therapeutic treatments – increases overall treatment costs in the final analysis.

Therefore the demand for real three-dimensional imaging (that is, with the isotropy of the voxels) has been present in MRT for some time now. It was successfully resolved by using gradient-echo based (GRE) MR sequences for T1-weighted (w) imaging. For this reason, these techniques used in modern MRT are a permanent feature of examination protocols and an important part in the evaluation of pathologies. Even though T2-similar contrasts are possible with the help of GRE MR sequences (examples in this case are the MEDIC or DESS sequences), for optimal image contrast with T2-weighting, a Spin Echo or Turbo Spin Echo (TSE) is required. The introduction of SPACE sequence technology (Sampling Perfection with Application optimized Contrasts using different flip angle Evolutions; SPACE) is an important prerequisites for using T2-weighted 3D imaging:

1. T2-weighted image contrast (SPACE is a variant of TSE),
2. true isotropic 3D data records with high resolution (voxel size ≤ 1 mm^3)
3. use of a large Field of View (FoV) and finally,
4. clinically acceptable measurement times [1, 2, 3].

Meeting these requirements is all the more important, because more questions will find their way into the clinical MR tomographic routine since the introduction of the Tim (Total imaging matrix) technology. These, based on the necessary acquiring of large FoVs, were previously the sole domain of MS CT. [4].

Application methods and their first clinical results

When using SPACE* for image generation in the torso, a number of factors have to be observed. Pulsations of large vessels and respiratory motion cannot limit image quality as compared to conventional MRT. In addition, the previously available patient preparation techniques have to be maintained. Since October 2004, SPACE is used within the framework of clinical routine for patients requiring high resolution T2-weighted 3D imaging as compared to conventional 2D MRT. Key emphasis are pathologies of the pelvis and the spine. Whenever necessary, (for example, for staging rectal carcinoma) an additional retrograde filling of the rectum with ultrasound gel is performed.To keep intestinal motion quiet as a function of the body weight, up to 1 or 2 vials of buscopan (n-butyle scopolamine) will be administered intravenously. The following were used as default values for previous routine applications of

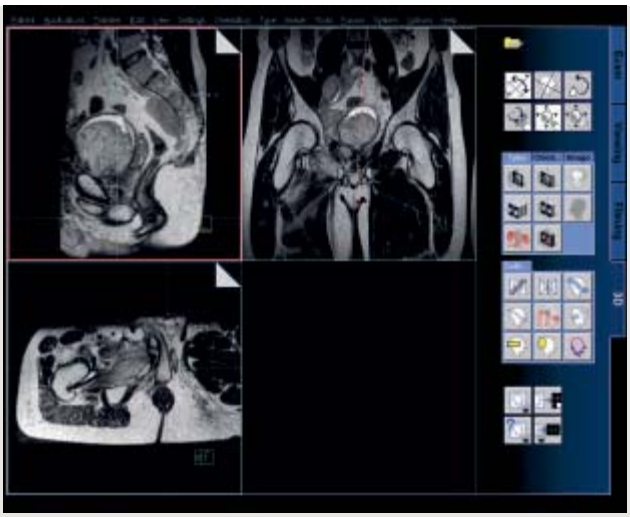

Figure 1 *T2 SPACE with PAT 3 of the pelvis.*
35-year-old patient with extended rhabdomyosarcoma invading into the bladder.
3D imaging with 1 mm³ isotropic spatial resolution allows retrospective slice prescription in any orientation needed.

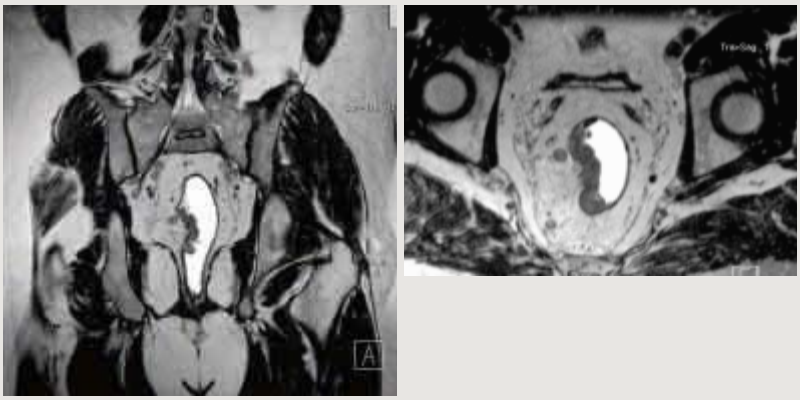

Figure 2 *T2 SPACE with PAT 3 of the pelvis 1 mm³ isotropic spatial resolution.*

43-year-old patient with rectum carcinoma with transgression of lamina propria /T3).
The 3D dataset was acquired in coronal orientation (left) and reconstructed in axial direction (right).

Figure 3 *T2 SPACE with PAT 3 of the spine. 1 mm³ isotropic spatial resolution.*

Female 13-year-old patient with
- *Arnold Chiari III*
- *Scoliosis*
- *Multiple segmentation disorders of the spine*

The isotropic 3D dataset acquired in coronal orientation (left) and a curved-cut reconstruction along the spine (right).

** The information about this application is preliminary. The application is under development and is not commercially available in the U.S., and its future availability cannot be ensured.*

SPACE: TR/TE = 1500/124 ms, 2 averages, Field of View (FoV) = 380 mm, 144 slices per slab, base matrix = 384, iPAT Factor = 3 (GRAPPA, 24 reference lines, triple matrix mode), Turbo Factor = 71, resulting isotropic voxel size $(1.0\ mm)^3$ (no interpolation), resulting measurement time 10 min, 32 seconds. It should be noted as well that the repetition time (TR) is shorter by using a restore pulse. All measurements are performed at a MAGNETOM Avanto system. Depending on the region to be examined, a variable combination of body and spine Matrix coils were implemented (when displaying the cervical spine/neck, an additional neck, head coil combination was used).

During the first 50 patients (21 females, 29 males, medium age 49 years, minimum 2 and maximum 79 years), the following regions were examined with SPACE: pelvis n = 30, lower spinal column n = 12, upper spinal column n = 6, extremities n = 4. Of 10 patients, the entire cohort was transferred for staging of a rectal carcinoma and a rectal filling with ultrasound gel was performed. In 2 cases, the entire spine was imaged using an automatic table feed followed by combining the images with a composing function of the scanner. Although it was possible to observe changes in the contrast characteristics of individual tissues to one another by using a restore pulse and variable flip angles (that theoretically led to a slight T1-dependency), the diagnostic quality obtained was not limited. Also, every case showed that the signal-to-noise ratio (SNR) was equivalent to conventional 2D T2-weighted imaging.

The same applies to the contrast-to-noise impression (CNR) of the SPACE sequence with respect to the diagnostic quality. Again, it can be considered equal to conventional T2-weighted imaging. We did not observe an increase in artifacts caused by e.g. metallic clips or implantations [5].

Conclusion and future considerations

What is decisive in using SPACE combined with Tim in the torso is the fact that the display of complex anatomical and pathological interactions and changes is possible in routine applications by means of MRT. It allows for the visualization of systemic disease aspects (for example, complete display of scoliosis) and enables at the same time a detailed view of the local situation (for example, proof of a small syrinx). In addition, this technology combines the advantages of T2-weighted MRT with high resolution and true 3D imaging.

Another critical point that deserves mentioning in our initial clinical experience is the fact that the diagnostic advantages are fully applied only in the presence of a widely available reconstruction software. This is especially important within the framework of interdisciplinary discussions. Our institute uses the SPACE sequence exclusively as required by the speciality – especially for planning large operative spinal column or pelvic interventions. Multiplanar reconstructions are dialog-driven via the radiologist or operator. Additional research is required to determine whether SPACE is suitable for replacing the previous 2D T2-weighted sequences used with previous examination protocols.

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