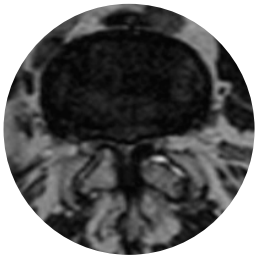

Comparison of volumetric and conventional sequences for the evaluation in magnetic resonance of the lumbar spine

Comparación de secuencias volumétricas con técnicas convencionales en resonancia magnética de columna lumbar

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Summary

Objective: To compare the protocol that includes the three-dimensional SPACE-3D sequence with the conventional protocol in the magnetic resonance imaging (MRI) study of patients with low back pain. ***Methods:*** A prospective study of diagnostic tests was carried out, in which MR images of the lumbar spine were taken from 40 patients using a conventional protocol and another protocol that included a volumetric sequence (SPACE-3D) in conjunction with axial T1 and sagittal STIR sequences, in a 1.5T resonator. The images were interpreted by two radiologists independently, both the conventional protocol and the protocol that included the volumetric sequence, one month apart. Both protocols were compared, calculating the sensitivity and specificity with the confidence interval (CI 95%), a value of p ≤0.05 using the Chi-square test was considered statistically significant. Variables such as the presence or absence of artifacts, disc protrusion/extrusion, narrowing of the central neural canal, lateral recess or root emergence foramen, and presence of radiculopathy, among others, were evaluated for both techniques. Inter- and intra-observer agreement was calculated using the Kappa index with a 95% CI. ***Results:*** it was found that the protocol that included the SPACE-3D sequence presents similar diagnostic performance (not inferior) when compared to the protocol with the conventional sequences for the variables evaluated, similarly, abnormal findings were detected, which allowed a complete study and diagnosis in less time. ***Conclusions:*** The diagnostic performance of the protocol that includes the SPACE-3D volumetric sequence is similar (not inferior) to the protocol with conventional sequences used in MRI of the lumbar spine and shortens the total study time.

Resumen

Objetivo: Comparar el protocolo que incluye la secuencia tridimensional SPACE-3D con el protocolo convencional en el estudio imagenológico por resonancia magnética (RM) del paciente con dolor lumbar. ***Metodología:*** Se realizó un estudio prospectivo de pruebas diagnósticas, en el que se tomaron imágenes por RM de la columna lumbar de 40 pacientes utilizando un protocolo convencional y otro protocolo que incluyera una secuencia volumétrica (SPACE-3D) en conjunto con secuencia axial con información T1 y sagital STIR, en un resonador de 1,5T. Las imágenes fueron interpretadas por dos radiólogos de manera independiente, empleando tanto el protocolo convencional como el protocolo que incluía la secuencia volumétrica, con un mes de diferencia. Se compararon ambos protocolos calculando la sensibilidad y la especificidad con el intervalo de confianza (IC 95 %), se consideró significación estadística un valor de $p \leq 0{,}05$ utilizando la prueba de Chi-cuadrado. Se evaluaron para ambas técnicas variables como presencia o no de artefactos, protrusión/extrusión discal, estrechez del canal neural central, receso lateral o foramen de emergencia radicular, radiculopatía. Se calculó la concordancia inter e intraobservador utilizando el índice Kappa con un IC 95 %. ***Resultados:*** Se encontró que el protocolo que incluye la secuencia SPACE-3D presenta rendimiento diagnóstico similar (no inferior) frente al protocolo con las secuencias convencionales para las variables evaluadas; igualmente, se detectaron los hallazgos anormales, lo cual permitió un estudio completo y un diagnóstico en menor tiempo. ***Conclusiones:*** El rendimiento diagnóstico del protocolo que incluye la secuencia volumétrica SPACE-3D es similar (no inferior) al protocolo con las secuencias convencionales utilizadas en RM de columna lumbar y acorta el tiempo total del estudio.

Introduction

Simple magnetic resonance imaging (MRI) is the test of choice to evaluate the lumbar spine in patients with low back pain. Traditionally, images are obtained with T1-, T2- and STIR-weighted sequences with axial and sagittal acquisitions; however, recently techniques have been implemented that use volumetric sequences (three-dimensional evaluation with better spatial reso-

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lution) with better anatomical definition, without altering the diagnostic yield and that decrease the time of the study (1-3).

Shorter MRI studies make their performance more tolerable in patients with pain and also in claustrophobic patients, as they improve patient quietness for optimal image acquisition and reduce the number of MRI scans under sedation (not evaluated in this study). Obtaining volumetric images with better spatial resolution and in less time, hypothetically allows the radiologist to speed up the MRI time.

There are new MR sequences that have expanded the arsenal of tools in the anatomical evaluation of the lumbar spine, one of them is the three-dimensional sequence with fast spin echo (FSE) enhanced in T2 with long echo train that produce images with similar characteristics to the two-dimensional sequences turbo spin echo (TSE) enhanced in T2 (1); This sequence takes its commercial name according to the brand of resonator in which it is performed, and includes the VISTA (volume isotropic turbo spin-echo acquisition) sequences from Philips and SPACE (sampling perfection with application-optimized contrasts using different flip angles evolution) from Siemens.

These sequences have many clinical applications: in neuroradiology-imaging of the skull and spine (2, 3), in the musculoskeletal system-evaluation of the knee and wrist (4, 5)-and in pelvic organ assessment (6). In 2013, when the authors initiated the research protocol they were not aware of prospective studies assessing the usefulness in the anatomical assessment of the spine.

The interest in the SPACE sequence stems from its ability to reduce artifacts, such as susceptibility, flow and chemical drift, by means of smaller voxels, short echo spacing (ultrashort echo time) and excessive refocusing of the radiofrequency pulse (refocusing pulses) (7, 8). In addition to the good anatomical definition, due to the lower susceptibility to artifacts of the SPACE sequence, it can be used in the evaluation of patients with metallic osteosynthesis material (7, 9-11).

Due to the aforementioned characteristics, volumetric sequences allow performing a protocol with a smaller number of sequences in different axes and thus reduce the time of the examination. Most of those who undergo MRI of the lumbar spine present pain of mechanical etiology (12, 13) and with these patients it is possible to reduce the number of sequences and the duration of the examination, with greater anatomical definition according to some studies (14). The prospective study by Swami et al. (12), demonstrates the non-inferiority of volumetric sequences, with excellent concordance between the two groups of sequences and with the benefit that the SPACE sequence is acquired in a quarter of the time used in conventional sequences.

According to the review of the recent literature and with the initial experience with the SPACE three-dimensional sequence, the authors of the work documented here believe that the implementation of a lumbar spine MRI protocol that includes the SPACE three-dimensional sequence in patients with low back pain provides similar or better diagnostic information to the conventional protocol and additionally in less time; with this hypothesis, a prospective and descriptive study was designed and carried out, with the main objective of comparing the diagnostic performance of the protocol that includes the SPACE three-dimensional sequence with the conventional protocol in the MR imaging study of the patient with low back pain.

The secondary objectives of the study were: 1) to describe the sociodemographic and clinical characteristics of patients with low back pain who participated in the study; 2) to compare the duration times of the protocol with conventional sequences vs. the protocol that includes SPACE-3D sequences, 3) to evaluate the intra and interobserver agreement between the two radiologists who interpreted the images.

Methodology

Type of study

This was a prospective observational study of diagnostic tests performed in an advanced diagnostic imaging center in Medellín, Colombia, with images obtained without the administration of intravenous contrast medium.

Eligibility criteria

Patients over 18 years of age with low back pain and indication for MRI in whom the images were obtained at the aforementioned institution were included. Patients with a history of lumbar spine surgery, suspicion of infection, vertebral metastatic compromise, traumatic history or who presented scoliosis were not included.

Population and sample

The first 40 consecutive patients meeting the described inclusion criteria, which were performed on two 1.5T resonators of the institution (Siemens Avanto and Siemens Essenza) between June and July 2016, were studied. This sample was the basis for the performance evaluation of the protocol including the SPACE volumetric sequence compared to the protocol of conventional sequences, as well as for the assessment of interobserver concordance between the two radiologists. For the evaluation of intraobserver agreement, MRI images of five patients were randomly selected. These images were interpreted twice by each radiologist, in two independent sessions also performed at different times.

Description of the lumbar spine MR protocols

In the 40 patients who made up the study sample, axial sequences with T1 and T2 information, sagittal sequences with T1, T2 and STIR information and three-dimensional SPACE T2 sagittal sequence were obtained in the same lumbar spine MRI session. For the interpretation of the lumbar spine MRIs by the two radiologists, each of them evaluated the MR images in independent sessions for the interpretation of the two protocols. The images of each patient were anonymized and the interval between the interpretation sessions was at least one month. The conventional interpretation protocol included axial sequences with T1 and T2 information and sagittal sequences with T1, T2 and STIR information; the protocol with the three-dimensional SPACE T2 sequence included this volumetric sequence and, in addition, axial sequences with T1 and sagittal STIR information.

Variables

The clinical information was collected by the nursing staff of the institution, who received training on the format for acquiring the information prior to the beginning of the collection of the patients; the inclusion and exclusion criteria were explained to them. In addition to the symptoms reported by the patient, imaging findings such as anatomical evaluation,

presence of artifacts, disc alterations, facet alterations, presence of spondylolysis or spondylolisthesis were included, changes in the signal of the Modic type vertebral plates, radiculopathy, narrow canal, foraminal stenosis, lateral recess stenosis, fluid in interfacet joints, synovial cysts, bone marrow edema and alteration of the cauda equina.

For some diagnostic findings their presence or absence was evaluated and for others the degree of involvement (0-25, 26-50, 51-75 and 76-100 %). The severity of the lesions was evaluated as: absent, mild, moderate and severe.

Data collection methods

The MRI studies were interpreted independently by two radiologists with more than 10 years of experience in MRI; the protocol with conventional sequences and the protocol that included the volumetric sequence were interpreted in independent sessions with an interval of more than one month between each session. In addition, prior to the start of the study, a pilot test was performed with the aim of measuring intraobserver agreement, which consisted of a double reading of the protocol with conventional sequences and the protocol that included the volumetric sequence, by the same radiologist. This was performed in five randomly selected patients.

Statistical analysis

The sociodemographic characteristics of the included population were analyzed by calculating the absolute and relative frequencies for qualitative variables and the median and quartiles for age, since this variable did not follow a normal distribution. The comparison of the evaluation of the lumbar spine by means of the protocol with the volumetric sequence and the protocol with the conventional sequences was made by calculating the sensitivity and specificity with their respective 95% confidence interval. The result of the protocol with conventional sequences was considered as the reference test. The Chi-square test was used to compare the positive percentages of detection of the different diagnoses of both techniques, with a value of $p<0.05$ being considered statistically significant. The inter- and intra-observer concordance was performed by calculating Cohen's Kappa value with the respective 95% confidence interval. The percentages of positive classifications of the two observers were also compared with the Chi-square test and a difference yielding a value of $p<0.05$ was considered significant. The statistical programs IBM SPSS Statistic 22 (IBM Corp., 2013. Armonk, NY: IBM Corp.) and Epidat. Program for epidemiological analysis of tabulated data v.3.1 (Galicia, Spain 2006).

Ethical considerations

This was a risk-free study according to Colombian Resolution 8430 of 1993 and had the approval of the Ethics Committee of the School of Health Sciences of the Universidad Pontificia Bolivariana.

Results

The studies were performed on two 1.5T resonators (Siemens Avanto and Siemens Essenza). The duration of the protocol with conventional sequences in the Siemens Avanto resonator was 16 minutes and 33 seconds and in the Siemens Essenza resonator it was 15 minutes and 55 seconds. The protocol that included the volumetric sequence (SPACE T2) and the sagittal STIR and axial T1 sequences had a duration on the Siemens Avanto resonator of 9 minutes and 23 seconds and for the Siemens Essenza resonator 9 minutes and 7 seconds. All images were acquired with a 16-channel column coil. The duration time of the sequences is preset in each resonator and thus the duration of each sequence of each protocol was added to obtain the total study time for both the conventional protocol and the protocol that included the volumetric sequence.

Of the 40 patients included, 55 % were women, the median age of the patients was 53.5 years (RIC: 30.0-66.5). In 26 (93.3 %) patients, pain irradiation to an extremity was described and five (19 %) of them had a positive Lasègue test. Among the associated symptoms according to the order of referral, paresis (2.5 %), paresthesia (12.5 %) and a history of fibromyalgia (2.5 %) were found (Table 1).

Table 1. Sociodemographic characteristics of patients evaluated with MRI of the lumbar spine, volumetric and conventional techniques

Characteristic	*n*	(%)
Sex		
Female	22	(55,0)
Male	18	(45,0)
Age in years		
Median (Q1 - Q3)	53,5	(30-66,5)
Laterality		
No	1	(3,2)
Left	15	(48,4)
Right	9	(29,0)
Bilateral	6	(19,4)
Lasègue		
Positive	5	(50,0)
Negative	5	(50,0)
Irradiation		
No	1	(3,7)
Positive	26	(96,3)
Other symptoms		
None	34	(85)
Fibromyalgia	1	(2,5)
Paresis	1	(2,5)
Paresthesias	5	(12,5)

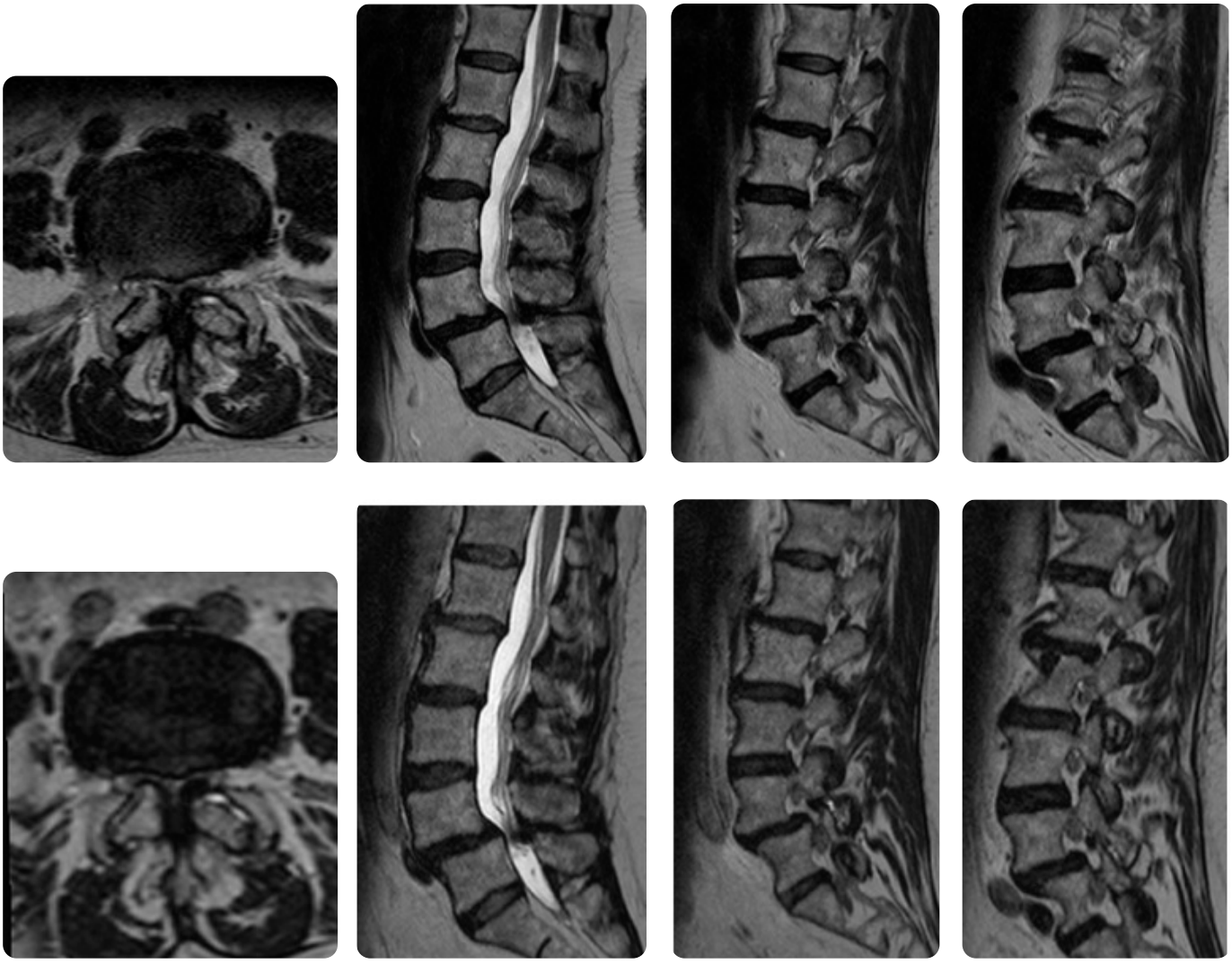

Figure 1. Severe narrow central neural canal L4-L5. Images of the sequences with 2D T2 information of the conventional protocol (upper images): a) axial in L4-L5 vertebrae, b) sagittal midline, c) right parasagittal, d) left parasagittal. Images of the SPACE 3D sequence with T2 information of the same patient (lower images): e) axial reconstruction, f) midline sagittal, g) right parasagittal and h) left parasagittal. Both radiologists reported severe narrow central neural canal and severe bilateral lateral recess stenosis at L4-L5, both in the conventional protocol and in the protocol with the SPACE 3D sequence. The narrow canal is secondary to degenerative spondylolisthesis, facet hypertrophy and enlargement of the yellow ligaments, with complete obliteration of cerebrospinal fluid within the thecal sac.

Regarding the detection of lumbar pathologies, the findings were similar for the great majority of variables in the protocols with volumetric and conventional sequence; no significant differences were detected between the two tests (table 2). Regarding central neural canal narrowing, the SPACE volumetric sequence was superior in the reading corresponding to radiologist 2, who identified 67.5 % while the conventional one was 41 %. However, there was a low sensitivity of 56%; this was the only variable with statistical significance, since in the other variables the percentage of detection was similar between both techniques. To determine the presence of artifacts, extruded discs, narrowing of the central neural canal, stenosis and severity of foraminal stenosis, Modic changes and detection of bone marrow edema, sensitivities greater than 90 % were obtained (Table 2).

The specificity for some variables changed significantly between both observers, and the most marked difference was in the detection of artifacts: 21.3 % for radiologist 1 and 80 % for radiologist 2. Given the discordance between both radiologists in the evaluation of all variables, their findings were analyzed independently (Table 2). For both radiologists the specificity was high, greater than 86.7% in the evaluation of central neural canal narrowing, narrow foramen and its severity, and in the evaluation of Modic changes and their degrees.

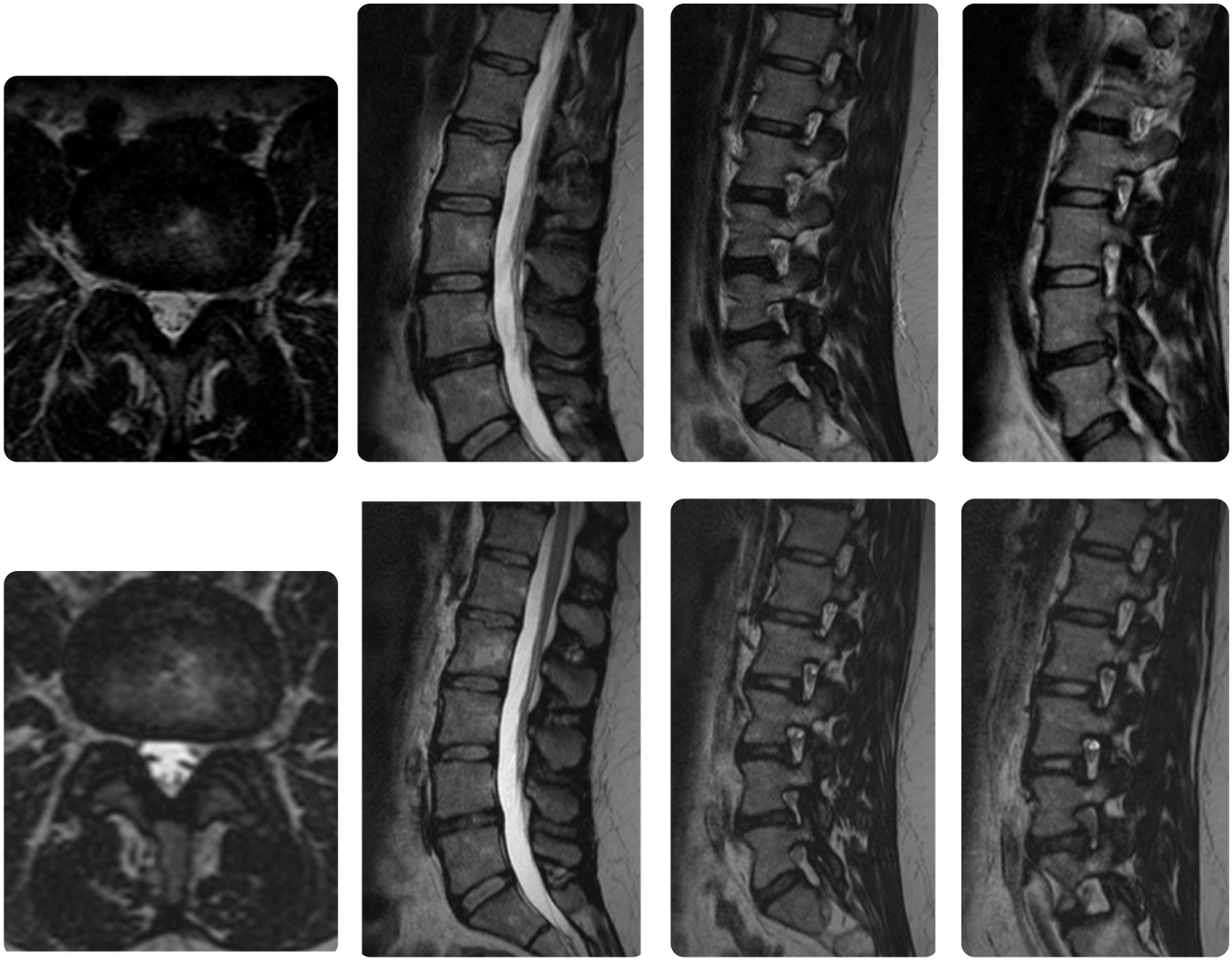

Figure 2. Severe left L4-L5 foraminal stenosis. Images of the sequences with T2 2D information of the conventional protocol (upper images): a) axial at L4-L5, b) sagittal midline, c) right parasagittal, d) left parasagittal. SPACE sequence images with 3D T2 information (lower images): e) axial reconstruction L4-L5, f) midline sagittal, g) right parasagittal and h) left parasagittal. Both radiologists reported severe left L4-L5 foraminal stenosis, both in the conventional protocol and in the protocol with the SPACE 3D sequence. The severe left L4-L5 foraminal stenosis is secondary to left L4-L5 foraminal disc extrusion with cranial migration into the foramen with compression of the left L4 nerve root at its foraminal segment. The central neural canal is wide and mild right L4-L5 foraminal stenosis is defined and also described by both radiologists in the two protocols.

Table 2. Operational characteristics of SPACE compared to the conventional technique for lumbar spine evaluation

Characteristic	R	Technique		p-value*	Sensitivity (95 % CI)	Specificity (95 % CI)
		SPACE	Conventional			
		n (%)	n (%)			
Artefacts	1	5 (12.5)	11 (27.5)	0.163	93.1 (82.16; 100)	27.27 (0.0; 58.14)
	2	9 (22.5)	5 (12.5)	0.377	85.71 (72.69; 98.74)	80 (34.94; 100)
Extruded discs	1	9 (22.5)	9 (22.5)	0.789	93.55 (83.29; 100)	77.78 (45.06; 100)
	2	10 (25)	9 (22.5)	1.000	87.1 (73.68; 100)	66.67 (30.31; 100)
Narrow channel	1	14 (35)	16 (40)	0.817	100 (97.92; 100)	87.5 (68.17; 100)
	2	27 (67.5)	16.4 (41)	0.033	56.52 (34.09; 78.96)	100 (96.88; 100)
Narrow foramen	1	22 (55)	16.84 (42.1)	0.362	77.27 (57.49; 97.06)	93.75 (78.76; 100)
	2	13 (32.5)	11 (27.5)	0.807	93.1 (82.16; 100)	100 (95.45; 100)
Narrow foramen severity	1	22 (55)	18 (45)	0.502	77.27 (57.49; 97.06)	94.44 (81.08; 100)
	2	13 (32.5)	11 (27.5)	0.811	93.1 (82.16; 100)	100 (95.45; 100)
Lateral recess	1	12 (30)	14 (35)	0.811	88.46 (74.26; 100)	64.29 (35.61; 92.96)
	2	17 (42.5)	16 (40)	1.000	79.17 (60.84; 97.5)	75 (50.66; 99.34)
Lateral recess severity	1	12 (30)	14 (35)	0.811	88.46 (74.26; 100)	64.29 (35.61; 92.96)
	2	17 (42.5)	16 (40)	1.000	79.17 (60.84; 97.5)	70.59 (45.99; 95.19)
Modic changes	1	14 (35)	15 (37.5)	1.000	96 (86.32; 100)	86.67 (66.13; 100)
	2	13 (32.5)	12 (30)	1.000	92.86 (81.53; 100)	91.67 (71.86; 100)
Modic grade	1	14 (35)	15 (37.5)	1.000	96 (86.32; 100)	86.67 (66.13; 100)
	2	13 (32.5)	12 (30)	1.000	92.86 (81.53; 100)	91.67 (71.86; 100)
Bone marrow edema	1	3 (7.5)	3 (7.5)	0.671	97.3 (90.72; 100)	66.67 (0.0; 100)
	2	3 (7.5)	1 (2.5)	0.608	94.87 (86.67; 100)	100 (50; 100)
Radiculopathy	1	17 (42.5)	19 (47.5)	0.822	90.48 (75.54; 100)	78.95 (57.98; 99.91)
	2	31 (77.5)	23.56 (58.9)	0.127	56.25 (28.82; 83.68)	100 (97.83; 100)
Protruded discs	1	13 (32.5)	11 (27.5)	0.807	79.31 (62.84; 95.78)	63.64 (30.66; 96.61)
	2	24.6 (61.5)	21 (52.5)	0.559	52.63 (27.55; 77.71)	75 (53.52; 96.48)

R: radiologist, 95 % CI: 95 % confidence interval, * p-value: Chi-square test

As can be seen in Table 3, Modic changes type I had the highest incidence for the two radiologists (64.68 % for radiologist 1 and 58.31 % for radiologist 2) and the most compromised vertebrae were L5-S1 also for the two radiologists (29.4 % for radiologist 1 and 33.33 % for radiologist 2).

Table 3. Changes Modic conventional protocol (reference test)

Vertebrae	Radiologist 1			Radiologist 2		
	Modic grade			Modic grade		
	I (%)	II (%)	III (%)	I (%)	II (%)	III (%)
L1-L2	11.76	0	0	0	8.33	0
L2-L3	5.88	11.76	0	16.66	0	0
L3-L4	23.52	0	0	16.66	0	0
L4-L5	17.64	0	0	16.66	8.33	0
L5-S1	5.88	23.52	0	8.33	25	0
Total	64.68	35.28	0	58.31	41.66	0

The narrow central lumbar canal (Figure 1) was more frequent in the L4-L5 vertebrae for both radiologists (72.21 % for radiologist 1 and 48.37 % for radiologist 2), additionally at this same height the highest percentage of severe narrow central canal was found (Table 4).

Table 4. Conventional narrow channel protocol (reference test)

Vertebrae	Radiologist 1			Radiologist 2		
	Severity			Severity		
	Mild (%)	Moderate (%)	Severe (%)	Mild (%)	Moderate (%)	Severe (%)
L1-L2	0	0	0	3.22	0	0
L2-L3	0	5.55	0	9.67	0	3.22
L3-L4	0	0	0	19.35	3.22	3.22
L4-L5	55.55	0	16.66	25.8	12.9	9.67
L5-S1	16.66	0	5.55	6.45	0	3.22

Foraminal (Figure 2) and lateral recess stenosis (Figure 1) were more frequent in the L4-L5 and L5-S1 vertebrae for both radiologists, as can be seen in Tables 5 and 6.

Table 5. Foraminal stenosis conventional protocol (reference test)

Vertebrae	Radiologist 1						Radiologist 2					
	Severity and laterality (%)						Severity and laterality (%)					
	Mild/ right	Mod/ right	Sev/ right	Mild/ left	Mod/ left	Sev/ left	Mild/ right	Mod/ right	Sev/ right	Mild/ left	Mod/ left	Sev/ left
L1-L2	0	0	0	0	0	0	0	0	0	0	0	0
L2-L3	2.08	4.16	0	4.16	4.16	0	0	0	0	0	0	0
L3-L4	2.08	6.25	0	2.08	4.16	0	4.34	13.04	0	0	8.69	0
L4-L5	10.41	8.33	0	10.41	8.33	4.16	13.04	4.34	4.34	8.69	8.69	8.69
L5-S1	4.16	10.41	0	4.16	10.41	0	4.34	8.69	0	4.34	8.69	0

Table 6. Lateral recess stenosis conventional protocol (baseline test)

Vértebras	Radiologist 1						Radiologist 2					
	Severity and laterality (%)						Severity and laterality (%)					
	Mild/ right	Mod/ right	Sev/ right	Mild/ left	Mod/ left	Sev/left	Mild/ right	Mod/ right	Sev/ right	Mild/ left	Mod/ left	Sev/ left
L1-L2	0	0	0	0	0	0	2.94	0	0	2.94	0	0
L2-L3	0	0	0	0	0	0	2.94	0	0	2.94	2.94	0
L3-L4	4.76	4.76	0	4.76	4.76	0	5.88	2.94	0	2.94	0	0
L4-L5	0	9.52	14.28	0	9.52	9.52	5.88	5.88	8.82	11.76	5.88	14.70
L5-S1	0	19.04	0	9.52	9.52	0	8.82	2.94	0	5.88	2.94	0

When assessing intraobserver agreement, perfect agreement was observed for all Kappa variables: 1.0 (95 % CI: 1.0-1.0); for the rest of the variables for which this indicator could not be calculated, because the diagnosis or characteristic was not presented, the assessment was 100 % concordant in both measurements and for both evaluators (data not shown). The results of this analysis are documented in Table 7.

Table 7. Intraobserver concordance for the evaluation of the lumbar spine with volumetric and conventional technique

Characteristic	Technique	Radiologist 1			Radiologist 2		
		Agreement (%)	Kappa	95 % CI	Agreement (%)	Kappa	95 % CI
Artifacts	SPACE	100	-	-	100	1	1.0 - 1.0
	Conventional	100	-	-	100	1	1.0 - 1.0
Extruded discs	SPACE	100	1	1.0 - 1.0	100	1	1.0 - 1.0
	Conventional	100	1	1.0 - 1.0	100	1	1.0 - 1.0
Narrow channel	SPACE	100	-	-	100	-	-
	Conventional	100	-	-	100	-	-
Narrow Foramen	SPACE	100	1	1.0 - 1.0	100	1	1.0 - 1.0
	Conventional	100	1	1.0 - 1.0	100	1	1.0 - 1.0
Severity Narrow Foramen	SPACE	100	1	1.0 - 1.0	100	1	1.0 - 1.0
	Conventional	100	1	1.0 - 1.0	100	1	1.0 - 1.0
Lateral recess	SPACE	100	1	1.0 - 1.0	100	1	1.0 - 1.0
	Conventional	100	1	1.0 - 1.0	100	1	1.0 - 1.0
Severity Lateral recess	SPACE	100	1	1.0 - 1.0	100	1	1.0 - 1.0
	Conventional	100	1	1.0 - 1.0	100	1	1.0 - 1.0
Modic changes	SPACE	100	1	1.0 - 1.0	100	1	1.0 - 1.0
	Conventional	100	1	1.0 - 1.0	100	1	1.0 - 1.0
Modic Grade	SPACE	100	1	1.0 - 1.0	100	1	1.0 - 1.0
	Conventional	100	1	1.0 - 1.0	100	1	1.0 - 1.0
Bone marrow edema	SPACE	100	1	1.0 - 1.0	100	-	-
	Conventional	100	1	1.0 - 1.0	100	-	-
Radiculopathy	SPACE	100	1	1.0 - 1.0	100	-	-
	Conventional	100	1	1.0 - 1.0	100	-	-
Protruded discs	SPACE	100	1	1.0 - 1.0	100	1	1.0 - 1.0
	Conventional	100	1	1.0 - 1.0	100	1	1.0 - 1.0

Agreement (%): Percentage of agreement between both measurements.
Kappa: Kappa could not be calculated because the evaluated characteristic did not vary among patients.
95% CI: 95% confidence interval.

The interobserver agreement (Table 8) presented variable values, the lowest agreements in the evaluation of artifacts and bone marrow edema had a Kappa lower than 0.09 and -0.08, respectively. The interobserver agreement for both protocols in the evaluation of Modic changes and in the determination of Modic grades yielded Kappa values above 0.8.

Table 8. Interobserver agreement for the evaluation of the lumbar spine according to magnetic resonance technique

Characteristic	Technique	Radiologist 1	Radiologist 2	p* value	Kappa	95 % CI
		n (%)	n (%)			
Artefacts	SPACE	5 (12.5)	9 (22.5)	0.3774	-0.0213	(-0.30; 0.26)
	Conventional	11 (27.5)	5 (12.5)	0.1623	0.0943	(-0.21; 0.40)
Extruded discs	SPACE	9 (22.5)	10 (25)	1.0000	0.7931	(0.57; 1.00)
	Conventional	9 (22.5)	9 (22.5)	0.7889	0.5699	(0.26; 0.88)
Narrow channel	SPACE	14 (35)	27 (67.5)	0.0073	0.4118	(0.20; 0.62)
	Conventional	17 (42.5)	19 (47.5)	0.8222	0.6977	(0.48; 0.92)
Narrow foramen	SPACE	22 (55)	13 (32.5)	0.0714	0.4686	(0.23; 0.71)
	Conventional	19 (42.1)	11 (27.5)	0.3443	0.5728	(0.32; 0.82)
Narrow foramen severity	SPACE	22 (55)	13 (32.5)	0.0714	0.4686	(0.23; 0.71)
	Conventional	18 (45)	11 (27.5)	0.1629	0.5288	(0.28; 0.78)
Lateral recess	SPACE	12 (30)	17 (42.5)	0.3522	0.6277	(0.39; 0.87)
	Conventional	14 (35)	16 (40)	0.8174	0.4681	(0.19; 0.75)
Lateral recess severity	SPACE	12 (30)	17 (42.5)	0.3522	0.6277	(0.39; 0.87)
	Conventional	14 (35)	16 (40)	0.8174	0.4681	(0.19; 0.75)
Modic changes	SPACE	14 (35)	13 (32.5)	1.0000	0.8324	(0.65; 1.00)
	Conventional	15 (37.5)	12 (30)	0.6363	0.8333	(0.65; 1.00)
Modic grade	SPACE	14 (35)	13 (32.5)	1.0000	0.8324	(0.65; 1.00)
	Conventional	15 (37.5)	12 (30)	0.6363	0.8333	(0.65; 1.00)
Bone marrow edema	SPACE	3 (7.5)	3 (7.5)	0.6712	-0.0811	(-0.15; -0.02)
	Conventional	3 (7.5)	1 (2.5)	0.6080	-0.0390	(-0.10; 0.02)
Radiculopathy	SPACE	17 (42.5)	31 (77.5)	0.0030	0.3533	(0.15; 0.56)
	Conventional	19 (47.5)	23 (57.5)	0.4258	0.2853	(-0.01; 0.58)
Protruded discs	SPACE	13 (32.5)	24 (60)	0.7500	0.3810	(0.14; 0.62)
	Conventional	11 (27.5)	21 (52.5)	0.0311	0.1198	(-0.15; 0.39)

P-value: Chi-square test

95% CI: 95% confidence interval.

Discussion

In the prospective study it was found that the protocol including the SPACE volumetric sequence had a similar (not inferior) diagnostic performance to the protocol using conventional sequences for the evaluation of all variables (except narrow channel assessment for radiologist 2) (Table 2), with a similar detection percentage for both radiologists. Similarly, the specificity of both techniques was similar, with the highest results in the assessment of narrow canal, narrow foramen and its severity, and Modic changes and their classification.

These results are similar to those obtained by Sung et al. (9), who found no significant differences when comparing both protocols (conventional and the protocol that included the SPACE 3D volumetric sequence in 3T resonator) for the evaluation of lumbar radiculopathy.

Additionally, in this work, the protocol with the SPACE volumetric sequence was superior for the detection of central neural canal narrowing for radiologist 2 (Table 2). This result was to be expected considering the multiple advantages described in previous studies of the 3D SPACE volumetric sequence, such as: 1) Decrease of partial volume effect in view of the fact that volumetric information is obtained with continuous thin slices (15). 2) The volumetric information obtained allows multiplanar reconstructions of the spine in any orientation, theoretically facilitating the assessment of the central neural canal, lateral recesses and conjunctival foramina, mainly in patients with altered spinal alignment, for example, with scoliosis. 3) No areas of the spine are left unstudied, as can happen with conventional 2D axial or sagittal slices. 4) Better spatial resolution (isotropic) is obtained than in 2D sequences (3, 9, 11, 5-17).

Validating the described possible advantages of the volumetric 3D sequence and the better performance in the present study of the protocol that included the 3D SPACE sequence for the diagnosis of narrow central neural canal by radiologist 2, recent studies describe a better diagnostic performance of the volumetric sequence compared to conventional 2D sequences. Hossein et al. (18) find that the 3D-SPACE sequence has better signal-to-noise ratio, better contrast-to-noise ratio, better visibility of all regions of the lumbar spine, with better interobserver agreement and in less time than 2D sequences, mainly in patients with scoliosis. Additionally, Sartoretti et al. (19) report that the high-resolution 3D volumetric sequence has a better

diagnostic performance than conventional 2D T2 TSE sequences for the visualization of lumbar nerve root involvement using a new 6-degree foraminal stenosis classification system.

In this study the intraobserver variability was excellent, with an agreement percentage of 100% for the two radiologists (table 7), which gives validity to the study.

When interobserver agreement was evaluated, it was found to be very low and independent of the protocol used. This last result suggests an observer dependence that contrasts with the results of other studies in which the interobserver agreement was better for volumetric sequences (3). This may be explained in the present study by the fact that before the interpretation of the MRIs there was no standardization of criteria in the interpretation of the images by the two radiologists, for example, with an initial test in which a joint evaluation of five studies was performed by the two radiologists to homogenize the interpretation of the findings and to harmonize the way in which the classifications were applied and understood. Possibly this factor increased interobserver variability, a limitation that should be avoided in future similar studies. Other studies, such as that of Sartoretti et al. (19), suggest that using more precise and detailed classifications, such as the classification used by them for 6-degree foraminal stenosis, may improve interobserver agreement.

A limitation of the work presented here was that the artifacts were evaluated together, i.e., if artifacts were present in the protocol group with conventional sequences or in the protocol that included the volumetric sequence, these were interpreted as positive for the group; However, as explained in the methodology, the protocol that included the SPACE sequence also included two sequences of the conventional protocol (sagittal STIR and axial T1), when the artifact appeared in any of the sequences that were present in both protocols, a positive value was given to both protocols, even if it was not present in the SPACE volumetric sequence, which is the sequence evaluated; This value was given in this way as it had been proposed in the initial protocol; however, it is important to highlight that none of the SPACE sequences presented artifacts in this study.

In the two lumbar MRI protocols of the present study, both the conventional and the SPACE sequence, an axial sequence with T1 information and a sagittal STIR sequence were included. When planning the study, it was considered important to maintain in the protocol with the SPACE sequence a sequence with T1 information, in this case, axial, to facilitate the characterization of focal and diffuse bone lesions. It was also considered important to maintain the sagittal STIR sequence in order to maintain a very good sensitivity to detect bone and soft tissue edema, which facilitates the diagnosis of infectious, inflammatory and tumor pathologies. It would be important for new studies in the future to define the usefulness of these additional sequences and the need or not of them accompanying the SPACE volumetric sequence in the evaluation of lumbar degenerative pathology.

The duration time of the studies was given as a constant, according to the time required by the resonator in image acquisition, partly because the patient never left the resonator while the images of the conventional sequences group and the SPACE sequence were taken; future studies could take the difference in image acquisition for both protocols in independent sessions in the resonator and define in a more precise way the difference in image acquisition time in both protocols. However, it has already been widely proven in the medical literature that the duration time for volumetric sequences is shorter compared to the acquisition time for conventional sequences (1, 3, 9). Sartoretti et al. (19), in a recent study, describe a new faster 3D SPACE sequence in which they use a new acceleration technology with "compressed sensing", which also allows improving the spatial resolution, an attractive sequence to be used in future studies.

In conclusion, and similar to previous studies, the diagnostic performance of the protocol that includes the volumetric sequence is equal (not inferior) to that of the protocol with conventional sequences, additionally, with a shorter duration in the acquisition time of the images. The authors recommend the use of volumetric sequences in the evaluation of low back pain of mechanical etiology in which the indicated examination is a simple MRI.

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