Automated Scan Plane Planning for Spine MRI using 2D Scout Images

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Introduction

The typical workflow of a manual scan plane setup requires careful positioning and repetition of the same task at each examination. Thus, the manual scan plane setup is stressful for the operator. Furthermore, although consistent scan planes are useful for follow-up examinations, manual scan planes suffer from inter-operator variability. Therefore, automated scan plane planning is expected to improve MRI scanner usability and to provide consistent scan plane prescriptions. In the past, automated systems for various examination regions have been demonstrated [1-3]. These systems use 3D image data to prescribe a scan plane, while the manual scan plane setup uses 2D multi-slice images. We previously proposed an automated scan plane planning method for the brain using 2D multi-slice orthogonal three-plane scout images, and showed that the method proved useful for quickly setting up scan planes [4]. An advantage of using 2D scout images is not only the shorter acquisition time, but also the smaller image data size than that of 3D. Therefore, the processing time for automated scan plane prescription is shorter than other methods that use 3D data. However, the manual scan plane setup for a spine examination is more troublesome than that for the brain.

In this paper, we propose a novel automated scan plane planning method for spine MRI using 2D scout images. We applied the proposed method to healthy volunteers and compared automatically defined scan plane positions with manually defined scan planes. The compared results showed that the proposed method prescribed scan planes quickly with acceptable accuracy in clinical practice.

Method

In our method, image recognition techniques extracts specific lines parallel to the required scan plane from 2D scout images of multi-slice orthogonal three-plane (axial, coronal, and sagittal). Our method automatically prescribes three 'sagittal', 'vertebral disk', and 'myelography' scan planes. The sagittal scan plane (S plane) was defined as parallel to lines both connecting the centrum of a vertebra with the nerves of the spinal cord in axial scout images and the longitudinal direction of the spine in coronal scout images. The vertebral disk scan plane (V plane) was defined as parallel to a gradient of a vertebral disk in the sagittal scout images and perpendicular to the running direction of the vertebral body in the coronal scout images. The myelography scan plane (M plane) was defined as parallel to the the longitudinal direction of the spine in the coronal and sagittal scout images. The procedures were as follows. In the first step, a line connecting the centrum of a vertebra with the nerves of the spinal (L1) cord was extracted from the axial scout images. In this step, pattern match processing using a characteristic tissue contrast was performed. In the second step, a line parallel to the longitudinal direction of the spine (L2) was extracted from the differential image and the lower signal intensity region of the coronal scout images. This is because the signal intensity of the vertebral body is lower than that of the surrounding tissue. In the third step, the gradient of the S plane was calculated using L1 and L2, and the center position was defined using the center position of the scout image and the centrum position of a vertebra. In the fourth step, the S plane image was reconstructed by interpolating the signal intensity from the sagittal scout image as in multi planar reconstruction (MPR). In the fifth step, the lines parallel to vertebral disks (L3) and the line parallel to the longitudinal direction of the spine (L4) were extracted from the S plane image, and a line perpendicular to the S plane (L5) was calculated. The spacial location of the V plane was calculated using L3, L5, and the position of the vertebral disks. The spacial location of the M plane was calculated using L4, L5, the center position of the scout image, and the position of the nerves of the spinal cord. The procedure was optimized according to the examined regions of the spine (cervical, thoracic, and lumbar spine).

Scout images were acquired using an RF spoiled steady-state acquisition with rewound gradient echo (RSSG) sequence on a 1.5-T system (ECHELON Vega®, Hitachi Medical Corporation, Japan) with a CTL coil. The scout scan was performed at the cervical, thoracic, and lumbar spine. Scan parameters were as follows: TR/TE = 30/1.5 ms, FOV = 350 mm (270 mm for the cervical spine), matrix size = 256 × 128, thickness/interval = 10/10 mm, flip angle = 10° (15° for the cervical spine), five slices each in sagittal, coronal, and axial orientations. The acquisition time was about 15 seconds. After obtaining written informed consent, 15 healthy volunteers were scanned. The processing of scan plane prescription was performed on an off-line platform. The entire process took 2 seconds on our platform (running Windows on Intel(R) Core(TM) 2 Duo, 3.0 GHz).

To estimate the accuracy of our method, the position of the automatically prescribed scan planes was compared to that of manually defined scan planes. Six estimators who were qualified radiological technicians manually accommodated three scan planes defined by our method. Here, the parameters of adjustment were the center positions of the scan planes (x, y, z) and turning angles around three orthogonal axes (θ_x, θ_y, θ_z). The evaluation value E defined as follows was calculated. $E(i) = \sigma_i - a(i)$, i = x, y, z, θ_x, θ_y, θ_z, where a(i) is average and σ_i is a standard deviation of adjustment amount between the six estimators. If E is a positive value, it means that the automatically defined scan plane positions fell within the range of the difference between operators.

Results and Discussion

Figure 1 shows examples of automatically prescribed scan planes of the cervical, thoracic, and lumbar spine. Table 1 lists the results of accuracy by the percentage of $E > -5$ (mm or degrees), which is acceptable accuracy in clinical practice, when E was evaluated for all 15 volunteers. The percentages in which an angular error fell within 5° were more than 90% for all cases. The percentages in which a position error fell within 5 mm were more than 90% except for two cases of z coordinates of S plane and M plane at the lumbar spine. The position error increased in these cases because our method defined z coordinates using the center of the scout image and did not factor in the variability of the superior-inferior direction depending on the patient's position. This problem can be easily solved using an extracted position of the vertebral disk in the S plane image.

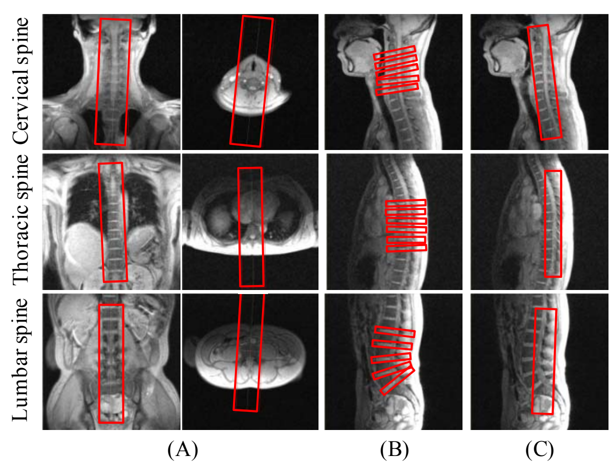

Figure 1: Three automatically prescribed scan planes. (A): S plane, (B): V plane , and (C): M plane.

Table 1: Percentage of $E > -5$ (mm or degrees), when E was evaluated for 15 volunteers.

	Scan plane	E(x)>-5	E(y)>-5	E(z)>-5	$E(\theta_x)>-5$	$E(\theta_y)>-5$	$E(\theta_z)>-5$
Cervical Spine	S plane	100	100	100	100	100	100
	V plane	100	97.3	100	98.6	100	100
	M plane	100	100	100	93.3	100	100
Thoracic Spine	S plane	100	100	100	100	100	100
	V plane	100	100	100	100	100	100
	M plane	100	100	100	100	100	100
Lumbar Spine	S plane	100	100	53.3	100	100	100
	V plane	100	100	100	100	100	100
	M plane	100	100	73.3	100	100	100

Conclusion

We have proposed a method for automatic scan plane planning for spine MRI using 2D scout images. The proposed method can prescribe scan planes quickly with acceptable accuracy in clinical practice.

References

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