Consistent automated scan planning of spine

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Introduction: The consistent planning of MRI scans between patients who undergo a spine examination is very important. It enables radiologists to investigate the patients anatomy with a preferred 'orientation' and is of great importance in follow-up studies and for the comparison between patients. However, operators have different opinions on the best planning based on their training, competence and experience. This may hamper the consistency between MR images of the spine. To deal with this problem, we developed automated scan planning for spine examinations. This reduces operator variation and bias, and enables the acquisition of the spine in a consistent manner which is preferred by the radiologist. Since the preferred planning can be shared between hospitals it will also be relevant for multi-site trials. The planning is part of an examination protocol that defines and automates the entire examination, thus improving workflow and achieving a one push button examination.

Methods: Automated spine planning is initiated by the execution of a 3D scout image of the region of interest. A set of anatomical landmarks including inter-vertebral discs, spinal cord, femur heads, and collar bones is automatically detected by non-rigid registration with an averaged atlas. The detected positions of the landmarks are used to guide the segmentation of the vertebrae by a model-based algorithm using 3D deformable mesh adaptation [1]. The vertebrae are then numbered consecutively, and the operator is asked to acknowledge the result. When the vertebrae are identified, corresponding subsets of mesh vertices are selected for each vertebra to be used as landmarks for automated planning.

The procedure aims to automatically plan each stack in the diagnostic scans. For a stack centered between vertebrae C3 and C4 this is done as follows. First, the landmarks of the C3 and C4 vertebrae on the scout image are compared with a training set which contains preferably landmarks for all vertebrae from minimal 10 patients, including the manual planning of the scans. The planning should have been performed locally by a skilled operator, and should reflect the (radiologists) preferred orientation of C3 and C4 in the MR images. The landmarks on C3 and C4 found in the scout image and the C3 / C4 landmarks in the training set are then compared and a best match is found by correlation registration [2]. The best planning of the stack can now be realized, since the preferred planning with respect to the C3 / C4 pair in the training set is known, and the difference in orientation between the C3 / C4 pair from the scout image and the training set is known.

The automated selection of the landmarks is the most challenging step in the procedure. Therefore, a confidence level is calculated which estimates whether the landmark detection is successful. If the confidence level is below a configurable level, the operator is notified that the automated planning is not possible and instructed to plan manually. The planning can be performed on multiple stacks in a single scan (as in Figure 2). Each stack is then independently planned towards its neighboring vertebrae. It is also possible to create a large stack covering more than two vertebrae. Then, all vertebrae inside the stack are used to calculate the optimal planning of that stack.

Results: For this study data from 28 patients acquired on a Philips achieva 1.5 T were assessed to evaluate the anatomical landmark detection. It was found that in around 80% of all cases the anatomical landmarks were positioned correctly. In Figure 1, the detection of landmarks of three patients is shown. Manually positioned ground truth landmarks are shown in green and the automatically positioned landmarks are displayed in red. The computing time per dataset was 2 minutes. The training set used for the study contained data from 2 volunteers examined repeatedly.

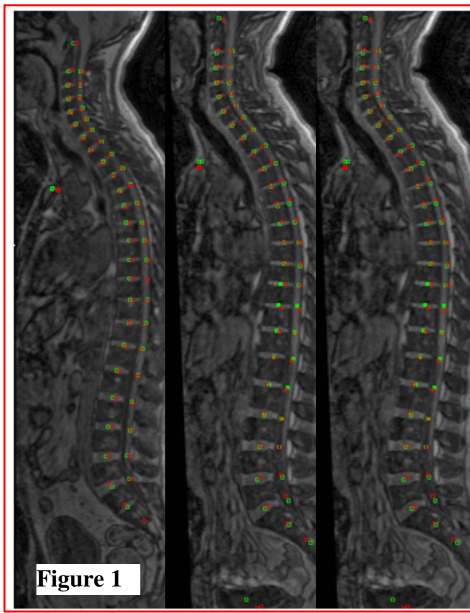
Figure 1

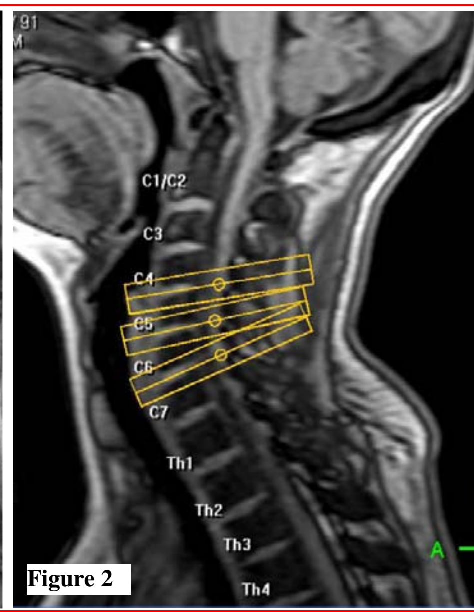

Figure 2

An example of the planning of 3 stacks in the cervical part of the spine is shown in Figure 2. The vertebrae have been segmented (not shown) and numbered. For the upper stack, C4 and C5 are used, for the middle, C5 and C6, and for the lower, C6 and C7. The orientation of each stack is unique and corresponds to the preferred orientation of the radiologist. The user only needs to accept the planning and the scan will be performed.

Discussion/ conclusion: We have shown that it is possible to automatically plan spine examinations. Planning can be performed for scans containing multiple stacks or on one stack covering multiple vertebrae. The suggested planning by the system is corresponding to the radiologists preference and is flexible to the anatomy under investigation (lumbar, thoracic, cervical). The challenging factor in the procedure is the recognition of the anatomical landmarks on the vertebrae. This part of the study has been tested extensively and found to be robust. To further evaluate the procedure we will use training sets that contain data from multiple patients to verify the robustness of the automated planning. Automated planning will improve the workflow and the quality of MR images, since it is fast, consistent and takes into account the radiologists preferred orientation of the spine.

References: [1] J. Weese, M.R. Kaus, et al. Proc. IPMI 2001, 380-387
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