Deep learning for fully-automatic quantification of avascular necrosis of the femoral head on 3D hip MRI in young patients eligible for joint preserving hip surgery: A pilot study

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INTRODUCTION & AIM

Size of necrosis is an important prognostic factor in the management of femoral head necrosis (AVN), which is usually estimated on radiographs and MRIs. Ideally, a fast-volumetric assessment of necrosis size would be desirable. Thus, we evaluated a deep-learning method to automatically quantify the necrotic bone in AVN.

METHOD & DATASET

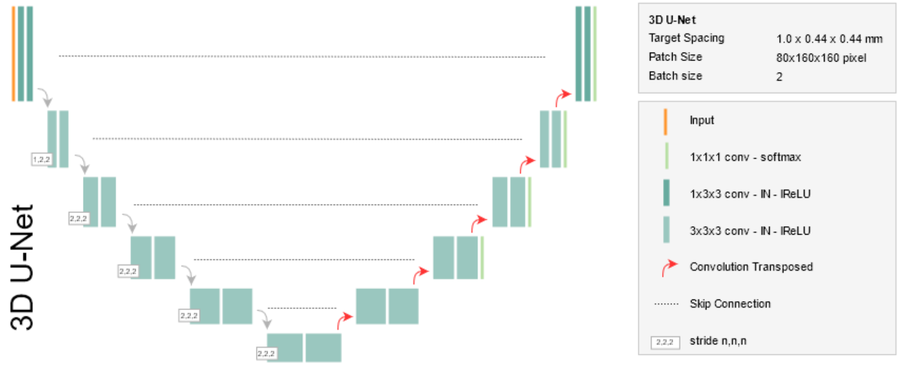

Figure 1. The architecture of the underlying 3D U-net is shown. The nnU-Net: a self-configuring method for deep learning-based biomedical image segmentation (Isensee et al. Nature Methods 2020) was used to train and predict the segmentation of the femoral head necrosis.

Dataset & Preprocessing

- The dataset contains 34 hip MR images with 2019 ARCO grading I: 3 hips; II: 5 hips; IIIA: 14 IIIB: 12; from the university hospital of Bern.
- Patients underwent preoperative 3T hip MRI including 0.8 mm^3 3D T1VIBE.
- All MR images were volume cropped and resampled to 80×160×160 voxels and 1×0.44×0.44 mm, respectively.
- 5-fold cross-validation was performed between manual and automatic volumetric analysis of absolute/relative necrosis volume.

EXPERIMENTS & RESULTS

The configuration with the best performance was the ensemble of the 2D and 3D U-net. The mean Dice coefficient for the vital femoral head bone and necrosis was 89±9% and 69±25%, respectively.

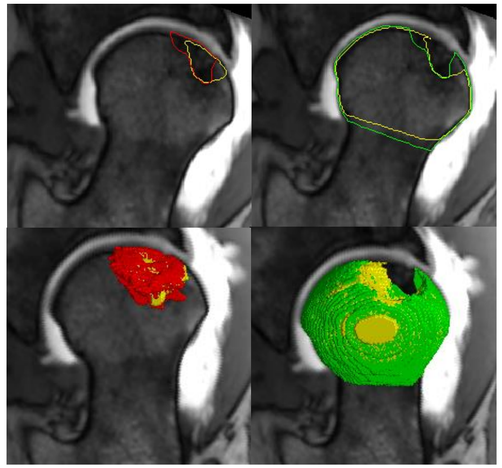

Figure 2. Visual segmentation results. Left: necrotic bone. Right: vital bone. Top: segmentation on axial oblique slice. Bottom: 3D model overlay. Red/Green: ground truth. Yellow: automatic segmentation.

Mean absolute and relative AVN volume was comparable between manual (8.2±7.4cm^3, 17±15%) and automatic (7.3±6.7cm^3, 15±14%) segmentation (both $p>0.05$) and showed a strong correlation (r_p = 0.90 and 0.92, respectively, both $p<0.001$). Manual and automated segmentation detected a difference (both $p<0.05$) in relative necrosis volume between early (ARCO I/II) and advanced (ARCO III) AVN: 8±8% vs 20 ±16% and 7±8% vs 18±14%, respectively.

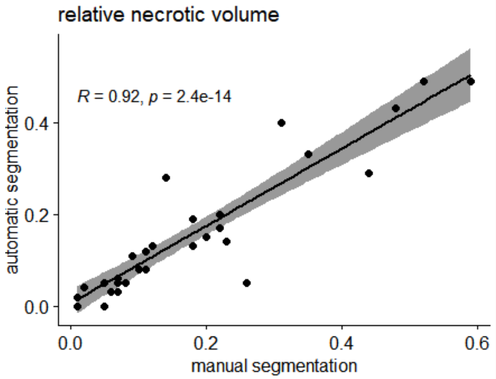

Figure 3. Scatter plot of relative necrotic volume. Manual vs. automatic segmentation.