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Automatic Glenoid Bone Loss Detection and Quantification in Shoulder CT Scans

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1 Purpose

Estimation of glenoid bone loss following shoulder dislocation in a CT scan is often required to determine what type of surgery is needed [1]. Currently, the best method for measuring glenoid bone loss has not been universally defined, so various methods have been proposed [2,3]. They can be grouped into linear-based (most methods) and area-based measurement methods, without (standalone) or with a comparison with the healthy contralateral glenoid, which is not always included in the CT scan. In all cases, the measurements are performed manually, which is time-consuming, requires expertise, and is subject to observer variability.

This paper presents a novel automatic standalone linear-based method for glenoid bone loss quantification in shoulder CT scans.

2 Methods

The method consists of a pipeline with four steps: 1) computation of an oblique plane in the CT scan that best matches the glenoid face orientation; 2) selection of the glenoid oblique CT slice; 3) computation of a glenoid best-fit circle, and; 4) quantification of the glenoid bone loss deficiency. The output is a report that includes the oblique slice with the best-fit circle overlaid on it, the circle origin and diameter, and the glenoid bone deficiency measure. The model-based method is the first to automatically and accurately compute the glenoid bone loss from a CT scan and provide a comprehensive report supporting clinical decision-making.

The first step of the pipeline consists of 1) finding the shoulder Region of Interest (ROI) by isolating the bone structures in the left/right shoulder; 2) computing the humerus and scapula segmentations by Hounsfield Units thresholding followed by morphological erosion and connected components analysis; 3) computing the glenoid segmentation by iterative dilation of the humerus contour, determination of its overlap with the scapula segmentation, and erosion; and 4) fitting a plane by Principal Component Analysis (PCA) to the resulting glenoid contour points.

The second step computes the oblique CT slice by rotating the CT scan so that the computed oblique plane is parallel to the axial CT slices, projecting the rotated glenoid segmentation onto the slices and selecting the one with the largest glenoid area. The result is the slice in which the glenoid contour appears the largest.

The third step computes the circle that best fits the inferior glenoid contour by first computing the glenoid contour of interest (COI), finding its main axis, computing the set a set of fitting circles by least squares distance optimization, and selecting the best fitting circle that satisfies surgeon-defined constraints formulated as glenoid clock constraints.

Finally, the glenoid bone loss is computed from the maximum normal distance between the glenoid contour and the best-fit circle in the one to five-o'clock ROI.

3 Results

The pipeline was evaluated on a dataset of 50 shoulder CT scans from 42 patients. Ground truth oblique slice, circle, and bone loss measurements were obtained from three clinicians. It achieved a mean oblique CT slice selection difference of 1.42±1.32 slices and a mean slice selection accuracy of 0.93±0.06, better than the intra-observer variability of 1.74±1.82 slices. The glenoid fit circle has a mean Average Symmetric Surface Distance (ASSD) of 1.32±0.52 mm and a mean best-fit circle distance of 2.47±1.06 mm. The glenoid bone loss measures have an Average Mean Error (MAE) Deficiency of 1.54±1.03 mm, a MAE Diameter of 1.88±1.40 mm, and a MAE Percentage Deficiency of 4.76±3.0 %, close to the intra-observer variability of 0.93±1.40 mm, 1.40±1.65 mm, and 2.98±4.97 mm, respectively. Fig. 2 illustrates the measures and shows the report.

4 Conclusion

To the best of our knowledge, our method for computing the glenoid bone loss from a shoulder CT is the first computer-aided method to measure glenoid bone loss with a linear-based standalone model automatically. It produces a comprehensive report consisting of necessary clinical measurements of glenoid bone loss, including 2D glenoid slice, best-fit circle, and glenoid bone loss measurement. Since the method is model-based, it produces explainable results and does not require extensive annotated training data [4]. Our experimental results show that our method achieves results close to the observer variability.

Automated quantitative analysis of glenoid bone loss in CT scans is practically viable and may assist orthopedic surgeons in selecting and planning surgical shoulder re-stabilization treatment [5].

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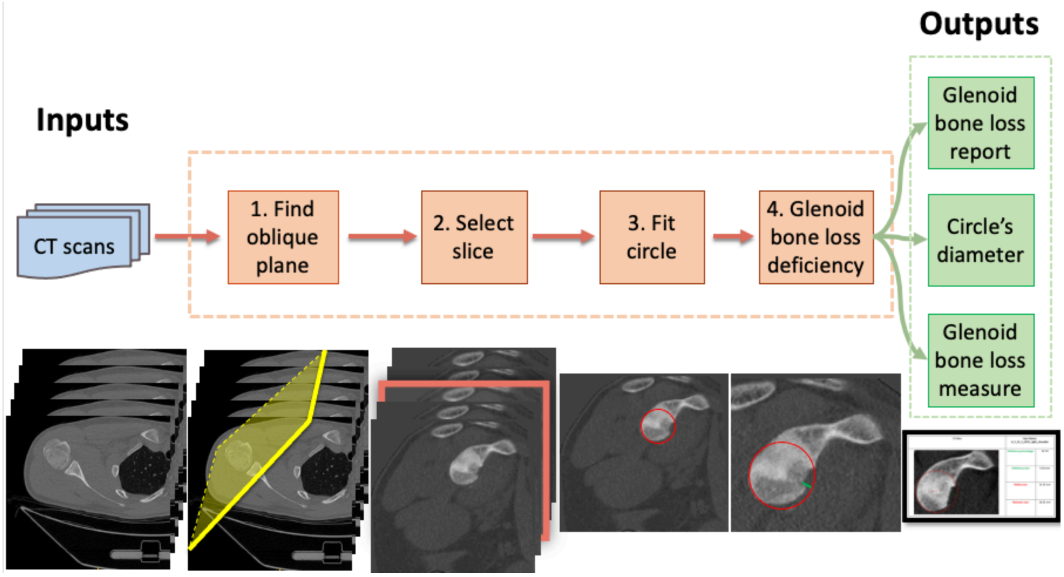
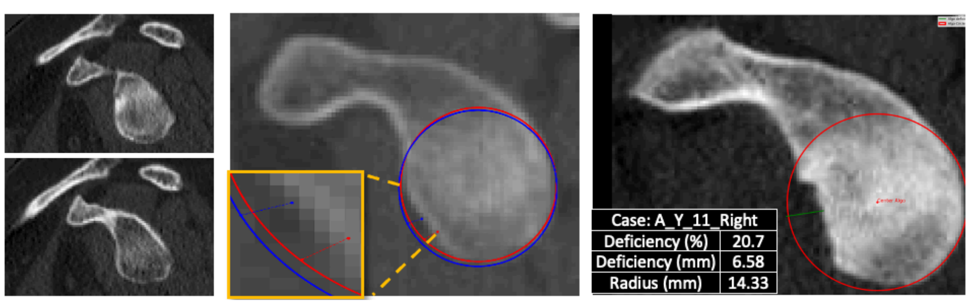


Figure 1: Block diagram of the pipeline for glenoid bone loss detection. The input is an upper body CT scan of patient (blue); the outputs are the glenoid circle diameter, the glenoid bone loss measure, and the glenoid bone loss report (green). The method steps are: 1) find glenoid-orientated oblique CT slice; 2) choose slices that contain the most glenoid bone in an oblique orientation; 3) fit circle around the inferior glenoid bone; 4) identify glenoid bone loss and extract measurements.



(a) (b) (c)

Figure 2: Illustration of: (a) ground truth and computed oblique CT slice; (b) ground truth (blue) and computed (red) best fit circle; (c) glenoid bone loss report showing the best fit circle (red) and the computed measures.