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Anterior shoulder stability restoration: quantifying the surgery type decision variability

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1 Purpose

Anterior shoulder dislocation is frequent, occurring in 23.9/100,000 person-years in the USA, mostly in males (72%) aged 15 to 29 (50%) [1]. Following a dislocation of the shoulder, glenoid bone loss (GBL) is common, occurring in ~40% of patients with a single dislocation and ~85% of patients with recurrent dislocations [2]. Glenoid bone loss may cause shoulder instability and may lead to recurrent dislocations, thus requiring surgery to restore stability [3]. Arthroscopic Bankart repair [4], an arthroscopic surgery to repair torn ligaments, is usually performed when the GBL is minor, while Latarjet coracoid process transfer [5] is required when the GBL is major.

The most common method for computing GBL from shoulder CT scans, described in [6], consists of finding the circle that best fits the posteroinferior glenoid contour in the oblique CT slice in which the glenoid face appears largest and measuring the largest radial distance l between the glenoid contour where the glenoid bone loss appears and the best-fit circle. The GBL % ratio is the ratio of the distance l and the best-ft circle diameter d: $GBL\_\%\_ratio = (l/d) \times 100$. Patients with a GBL % ratio that is less than < 13.5% are referred to Bankart repair surgery, while the others are referred to Latarjet process transfer surgery. The manual annotations and measurements required to compute the GBL % ratio are time-consuming and require expertise. To address these issues, we developed an automatic method that follows the steps of the manual annotation and measurement [7].

It is well known that establishing a ground-truth reference measurement is challenging due to intra-observer variability. This may lead to significant differences in the GBL % ratio and thus may lead to different surgical decisions, especially for borderline cases.

The goals of this study are: 1) to quantify the effect of the inter-observer variability on the surgical decision of Bankart vs. Latrajet procedures with the 13.5% GBL % ratio cut-off threshold; 2) to evaluate the variability between the manual and computed selection of the best-fit circle and of the largest radial loss distance l required to compute the GBL % ratio and quantify its impact on the surgical decision.

2 Methods

We retrospectively collected 51 shoulder CT scans from 44 patients (12 right and 39 left shoulders, 22 significant GBL and 29 with minor or no GBL) from the Hadassah University Medical Center, Jerusalem, Israel. We recruited three orthopedic surgeons with experience with anterior shoulder surgery for the study: two senior surgeons and one junior surgeon with 15+ and 8 years' experience.

Ground-truth annotations of the oblique CT slice selection, glenoid best-fit circle, and glenoid bone loss measurements were manually performed by the three surgeons on all CT scans using the ITK-SNAP [8] and Philips Q-Station [9] software. The surgeons manually annotated the glenoid best-fit circle, from which the circle diameter d was obtained, and the largest radial distance l between the glenoid contour where the glenoid bone loss appears and the best-fit circle. The GBL % ratio was then directly computed from these parameter values. In addition, the computed GBL % ratio was obtained with the fully-automatic method described in [7]. Fig. 1 shows the annotations for one of the cases.

We conducted two studies. Study 1 quantified the effect of the inter-observer variability on the surgical decision of Bankart vs. Latrajet procedures with the 13.5% GBL % ratio cut-off threshold. Each surgeon was asked to determine for each scan, which surgery to choose based on their manual measurement. We then computed the agreement/disagreement between the surgeons and the effect of replacing the threshold with an interval. Study 2 quantified the effect of the selection of the best-fit circle and the largest radial distance l. The surgeons were presented with four options (Fig. 1): the manual annotations of each one of the surgeons and the computed annotation. The GBL % ratio was shown for each annotation. Each surgeon chose one of the annotations – two if he found that the annotations were indistinguishable.

3 Results

For Study 1, we found that for the 20 cases in which the GBL % ratio was < 5% or > 25%, all three surgeons agreed on the surgical procedure. However, for the remaining 31 cases, there was disagreement in 13 cases (42%). When the cut-off threshold of 13.5% was replaced by the interval 12-16.5%, thereby creating three categories instead of two – Bankart, Uncertain, and Latrajet – the disagreement in the Bankart and the Latrajet categories disappeared. Moreover, we found that there was a disagreement in 25% of all cases between the junior and the two senior surgeons. For Study 2, Table 1 lists the results. In only about 30% of the cases, the surgeons chose their own annotation. Also, the computed annotations were selected at least as often as those of the junior surgeon.

4 Conclusion

The established GBL % ratio cut-off threshold of 13.5% may lead to significant discrepancies between surgeons regarding the type of surgery to be performed. Our study shows that replacing this single cut-off threshold with an interval (12-16.5%) and three categories instead of two may improve decision making by explicitly identifying the borderline cases for which there is no consensus between experts. Our study also shows that the computed GBL ratio % with the method described in [7] is within the observer variability for surgical decision-making and can thereby be reliably used to save time and increase decision consistency in selecting and planning surgical shoulder re-stabilization procedures.

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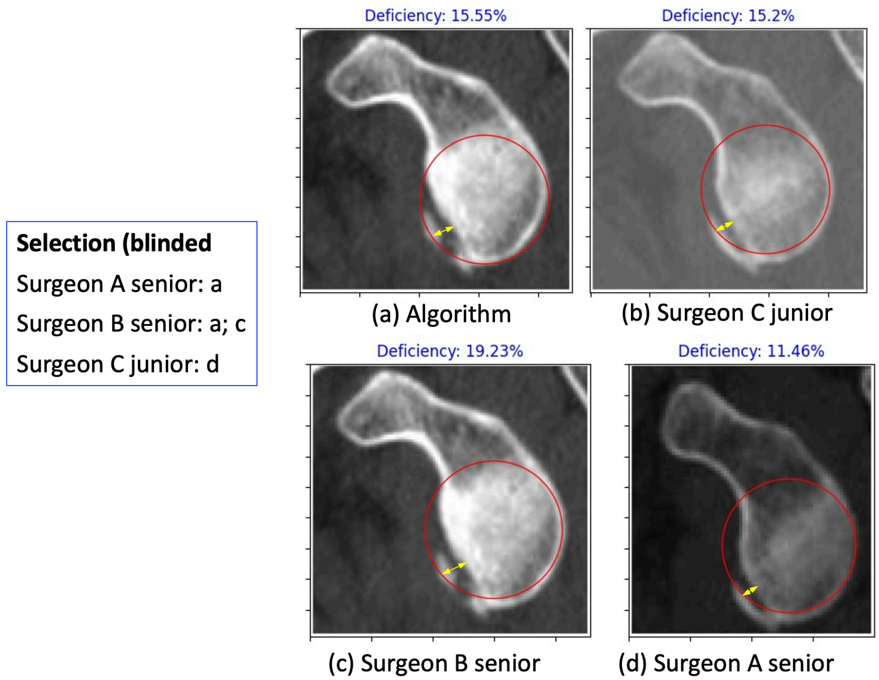

Fig. 1: Selection of the best-fit circle (red) and the largest radial distance between the glenoid contour and the best-fit circle (yellow) on the oblique CT slice where the glenoid appears largest by three surgeons: Surgeon A senior, Surgeon B senior, Surgeon C junior): (a) computed annotation; (b)-(d) manual annotations of each one of the surgeons; The computed GBL % ratio (Deficiency) is shown above each. Each surgeon had to choose one of the annotations – two if he found that the annotations were indistinguishable (left box).

Surgeon	A senior	B senior	C junior	Computed
A senior	**30.5%**	34.1%	18.3%	17.1%
B senior	23.3%	**33.3%**	18.4%	25.0%
C junior	25.3%	25.3%	**24.1%**	25.3%

Table 1: Results of the selection of the best-fit circle and largest radial distance between the glenoid contour and the circle. Columns: manual and computed annotations; rows: surgeon selection of one or two of the four annotations. Bold numbers indicate the % of the cases in which the surgeons chose their own annotation.