Quantitative and Subjective Analysis In Training Observers for Identifying the Deltoid Tuberosity on Radiographs

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INTRODUCTION: Interpreting plain radiographs is a cognitive and perceptual skill that requires time and dedication to hone. As shown in Hanley and co-workers' [1] comparative study between novice and experienced orthopaedic trainees, the novice trainees were significantly less accurate at locating and identifying unilateral acetabular fractures than the experienced trainees. Though proficiency in radiographic analysis is developed over time, perhaps better methods could be used in instructing and training the novice radiographic interpreter. Our study focuses on implementing the use of physical masking aids to help aid the eye for the detection of morphological landmarks in plain radiographs of the proximal humerus. Masking involves covering portions of an image that are unnecessary, as is common in post-processing of digital radiographs [2]. Masking reduces digital noise and thereby increases consistency throughout the visual display [3]. Digital noise, which refers to the inconsistencies of luminance that are added to the image via the display medium, is a well documented source of error in radiographic analysis [1]. While post-processing masking is helpful, perhaps providing the novice trainee a physical opaque object to act as a moveable mask, this technique can assist the trainee in reading radiographs. The physical mask could help by reducing excess digital noise and help focus the eye on the area of interest; thus, increasing efficiency, accuracy, and reliability in identifying features on radiographs of bone. Reliably identifying landmarks is important when radiographs of the proximal humerus are used to make simple measurements that correlate with bone quality. For example, simple radiographic measures of the relative distribution of cortical bone across the breadth of the proximal humerus shaft have been shown to correlate strongly with load carrying capacity and can be used to estimate local bone quality for applications in fracture risk stratification and management of humerus fractures [4-8]. One such example is demonstrated by Spross et al. [4], which requires the observer to reliably identify the proximal aspect of the deltoid tuberosity (DT) in order to make radiographic ratio measurements (outer diameter / inner diameter) that correlate with bone mineral density (BMD) and can be used to making decisions regarding management of proximal humerus fractures. The questions we address include: (1) Are there differences in identifying the deltoid tuberosity with the unaided eye compared to using an opaque masking aid? (2) Are differences between the unaided eye and masking aid the same for both novice observers and experienced clinicians?

METHODS: The proximal deltoid tuberosity (PDT) was grossly identified on thirty frozen human humeri (age range 14-65 yrs, 7 female, 23 male) and the distances between the top of the humeral head to the PDT were measured with digital calipers on the actual bones. The humeri were then oriented such that the deltoid tuberosity was the most pronounced and digitally radiographed. The unlabeled radiographs were first analyzed in a random fashion by a seasoned orthopaedic surgeon (J.G.S, observer 3, 22 years in clinical practice), and the humeri that had a visible and obvious DT (n = 21) were selected to be analyzed by novice observers (J.H.M. and N.W.C.), which eliminated the possibility of the novice observers (1 and 2) marking the PDT when one did not exist. The digital images were unlabeled and then randomly placed into separate collections. All three observers marked the PDT for each radiograph both with the unaided eye and with a masking aid, a 3 inch (76.2mm) by 5 inch (127.0mm) black index card. The observers used the same high-resolution computer monitor in a darkened room with the peripheral margins of the radiograph being darkened. Each observer was randomly assigned to identify the PDT with or without the masking aid first and made the second set of measurements three days later. Distances between the upper humeral head and the marked PDT (with masking and without a masking aid) on the radiographs were then measured (see Fig. 1). Results were evaluated using a one-way ANOVA and Pearson correlations for intra-observer comparisons.

RESULTS: As seen in Table 1, there were no statistically significant differences in measurements on the radiographs made using the unaided eye (no masking) compared with measurements made using a masking aid (all three observers, $p > 0.45$). Also marking the PDT on radiographs with the unaided eye vs. the measurements made directly on the bones did not reveal any significant differences for each observer. These results show that a masking aid does not increase accuracy when compared to the unaided eye. Notably, the subjective survey revealed that all three observers reported feeling more confident in their markings when using the masking aid and felt that using a masking aid made marking the PDT easier. Additionally, there were five instances where the difference between the unaided eye and the masking aid exceeded 10 mm, and only one instance where the difference exceeded 20 mm.

DISCUSSION: Although using the unaided eye may help to avoid detecting nuances and minor periosteal elevations that are not likely important when identifying bony landmarks such as the proximal deltoid tuberosity, the results of this study show that these are likely negligible in adequately identifying the clinically important landmark (edge of the PTD). We have shown in previous studies that statistically significant differences in bone strength only emerge when the radiographic measures that estimate bone quality are taken at distances great than 20 mm apart [7, 9]. Thus, our data suggest it is unlikely that making estimates of local bone quality using landmarks identified using the unaided eye compared to using a masking aid will result in clinically significant differences in risk stratification, fracture management, or classification of bone as osteoporotic or not. All observers preferred to use the masking aid, so clinicians and research observers should be advised to use whichever method that they wish. Possible limitations to this study include sample size. Also, nearly one-third of all radiographs had to be discarded from further analysis due to the lack of a clearly defined deltoid tuberosity. Further studies are warranted in radiographs of fractured bones, which might be obtained in various degrees of humerus rotation.

SIGNIFICANCE/CLINICAL RELEVANCE: There are no statistically or clinically significant differences in identifying the proximal deltoid tuberosity using the unaided eye compared to a masking aid for novice radiographic observers and an experienced orthopaedic surgeon.

REFERENCES: [1] Hanley et al. 2017 Iowa Orthop J, 37:225- ; [2] Peart 2009 Radiologic J, 81:90- ; [3] Samei 2005 RadioGraphics, 25:491- ; [4] Spross et al. 2015 Clin Orthop Rel Res 473:3038- ; [5] Tingart et al. 2003 JBJS 85:611-; [6] Mather et al. 2013 JSES 22:732-; [7] Skedros et al. 2016 J Orthop Res 34:331- ; [8] Nho et al. 2007 JBJS 89:44- ; [9] Langston et al. 2016 ORS abstract: 1655

Table 1: Comparison of Unaided Eye vs. Masking Aid

	Observer 1	Observer 2	Observer 3
Distance to PDT (Unaided Eye vs. Masking Aid on radiographs)	r = 0.959 p = 0.5	r = 0.913 p = 0.5	r = 0.923 p = 0.9
% Difference from True Value on actual bones (vs. Unaided Eye on radiographs)	Avg= 15.4% STD = 17.0 p =0.4	Avg= 14.2% STD = 17.1 p =0.5	Avg = 13.8% STD= 14.4 p =0.9
% Difference from True Value on actual bones (vs. Masking Aid on radiographs)	Avg = 14.3% STD = 15.4 p = 0.9	Avg = 15.0% STD = 16.1 p = 0.9	Avg = 14.8% STD = 16.3 p =0.9
Instances where difference exceeded 20 mm	0	1	0

Figure 1: Distance to PDT from top of Humeral Head