Techniques to evaluate glenoid bone loss

Hiroyuki Sugaya

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Abstract Assessing glenoid morphology as well as quantifying bone loss is critical when treating patients with recurrent anterior glenohumeral instability because this greatly affects surgeons surgical planning. Although many surgeons agree that 3-dimensionally reconstructed computed tomography (3DCT) images with humeral head digitally subtracted has been considered to be a gold standard when assessing glenoid morphology, there are some surgeons who are making an attempt to replace computed tomography with magnetic resonance imaging to reduce cost for imaging studies and avoid possible radiation exposure, and demonstrated that MRI was equally valuable as 3DCT to quantify glenoid bone loss. However, the role of preoperative imaging study is not only quantifying glenoid bone loss but to assess the glenoid shape and morphology to facilitate surgeons stabilizing the shoulder. In this view, 3DCT is the most recommended preoperative imaging study for bony tissue which provides critical and substantial information of the glenoid.

Keywords Glenoid bone loss · Shoulder instability · Glenoid morphology · Bony Bankart lesion · Attritional glenoid · Bone loss measurement · Radiography · 2DCT · 3DCT · MRI

Introduction

Bigliani coined the term glenoid rim lesions, which includes glenoid rim erosion and bony Bankart lesion, associated with recurrent anterior glenohumeral instability [1]. Bony Bankart lesion is generally believed to be a chronic condition followed by anterior glenoid rim fractures caused by acute glenohumeral

dislocation and/or subluxation with relatively high external force [2, 3]. On the other hand, glenoid rim erosion can occur as a result of repetitive friction between the humeral head and the anterior glenoid margin in patients with single or recurrent shoulder dislocations. According to a 3-dimensionally reconstructed computed tomography (3DCT) study with the humeral head digitally subtracted, the prevalence of glenoid rim lesion has been reported as high as 90 %, including 50 % of bony Bankart lesion and 40 % of erosion in shoulders with chronic recurrent traumatic anterior instability [4]. Interestingly, glenoid bone loss is relatively more significant in shoulders with bony Bankart lesion [5]. Many surgeons recognize that significant glenoid bone loss can be a cause of recurrence even after proper soft tissue surgical stabilization [1, 6]. In the meantime, Lo and Burkhart named significant bone loss as “inverted-pear glenoid” and “engaging Hill-Sachs lesion” and described that shoulders associated with these significant bone loss are not suitable candidates for arthroscopic soft tissue stabilization [7]. According to Burkhart and De Beer, glenoid bone loss greater than 25 % and/or the engaging Hill-Sachs lesion correlate with a recurrence of dislocation after arthroscopic soft tissue stabilization in approximately 67 % of patients, whereas shoulders without significant bone defect demonstrated recurrence as only 4 % [6]. In such cases with significant bone loss, they recommend open surgical bone grafting such as a Latarjet coracoid transfer [6]. Therefore, it is of supreme importance for surgeons to evaluate bone loss, both on the glenoid and humeral head side, prior to surgery because it strongly affects surgical planning.

Radiography and computed tomography

X-ray images are sometimes helpful in detecting the Hill-Sachs lesion and the anterior glenoid rim lesion, especially during the first patient visit. Bernageau described an effective method for

H. Sugaya (✉)
Shoulder & Elbow Center, Funabashi Orthopaedic Hospital, 1-833
Hasama, Funabashi, Chiba 2740822, Japan
e-mail: hsugaya@nifty.com

Fig. 1 A modified Bernageau method. Patients lie on their axilla in their most relaxed position. In this position, scapula needs to incline 5° to the vertical line (a). Then the incident X-ray needs to be aimed craniocaudally with 15° – 20° of inclination to the vertical line (b). With permission from Sugaya H. Chapter 14. Instability with bone loss. In: Angelo, Esch, Ryu, editors. AANA Advanced Arthroscopy: The Shoulder. Philadelphia: Elsevier; 2010. p. 136–46. [10]

detecting an anterior glenoid rim lesion with the patients in the standing position [8]. In fact, Edwards and colleagues reported that 79 % of shoulder with chronic anterior instability demonstrated anterior glenoid rim lesion using Bernageau method [9]. However, this technique requires fluoroscopic control in order to obtain optimal diagnosable images and, therefore, radiation exposure is an unignorable issue by the use of fluoroscopy. In the meantime, we have developed a modified Bernageau method with the patient lying on their axilla in their most relaxed position, which we called the “TV watching position (Fig. 1). In this method, clear X-ray images can be obtained more easily with a high probability of ascertaining bony pathology without using fluoroscopic imaging (Fig. 2) [10, 11]. Murachovsky and coworkers quantified glenoid bone loss by measuring the distance between the posterior and anterior glenoid rim on Bernageau images and concluded that this quantification provides similar result with that obtained from 3DCT [12]. However, although clearly obtained

Bernageau view is useful similar to axial images of 2-dimensionally reconstructed computed tomography (2DCT) for quantifying glenoid anterior-posterior bone loss [13, 14], it is still difficult for surgeons to predict and understand glenoid shape as well as measure the area of glenoid bone loss.

There is no doubt that 3DCT is the most important imaging study for assessing glenoid morphology accurately (Fig. 3) [4]. Preoperative 3DCT provides the following benefits: first, surgeons can recognize glenoid shape and the degree of bone loss intuitively at a glance; second, accurate quantification of bone loss can be possible by using an estimated inferior circle on the en face view of 3DCT; last, surgeons can easily assess the size and shape of the bony fragment in shoulders with bony Bankart lesion. This information greatly facilitates surgeons performing arthroscopic bony Bankart repair since normally it is difficult to identify configuration of the bony fragment during surgery because the bone fragment is embedded in the surrounding soft tissue [5, 15, 16].

Fig. 2 X-ray images obtained by the modified Bernageau methods. **a**, Normal glenoid (a black arrow indicates normal anterior glenoid contour). **b**, Glenoid with bone defect (a white arrow indicates the defect)

Fig. 3 3DCT images with humeral head digitally subtracted. **a**, Normal glenoid. **b**, Glenoid with bone defect

Quantification

Burkhart and coworkers proposed a unique method of quantifying glenoid bone loss arthroscopically utilizing the glenoid bare spot as the center of the inferior circle of the glenoid [17]. They measured the distance from the bare spot to the posterior margin of the glenoid and to the anterior margin of the glenoid. Then, the percentage of bone loss was calculated by dividing measured anterior distance by the posterior distance from the bare spot [17]. This method is easy and practical for clinical setting and can be estimated as a gold standard method of quantifying glenoid bone loss arthroscopically. However, since the cartilage at the anterior glenoid edge also eroded in addition to anterior bony edge, glenoid bone loss can be easily overestimated.

Several authors described glenoid bone loss measurement using preoperative imaging, especially using unilateral 2D and 3DCT [4, 5, 13, 14, 18–22]. Most of authors utilize assumed inferior circle of the glenoid using unilateral images on the affected side based on the fact that there is no side-to-side difference in normal shoulders [20, 23•]. Some authors proposed quantification methods using preoperative computed tomography (CT) images and justified them by comparing with the arthroscopic measurement described by Burkhart, et al [18, 19]. However, arthroscopic measurement as well as radiographic and 2DCT quantification is a typical 1-dimensional measurement which stands for a ratio of the width of missing bone to the anteroposterior diameter of the uninjured glenoid [12, 13, 17]. Several authors prefer to measure the bone loss 2-dimensionally as a ratio of the surface area of missing bone to the surface area of a best-fit circle over the inferior glenoid using 3DCT (Fig. 4) [4, 5], or other type of CT images seeking universally accepted technique for accurate quantification of glenoid bone loss [21, 22].

It is generally accepted that CT, especially en face view of 3DCT images, is the most preferable preoperative imaging

study for quantification of glenoid bone loss. However, several authors are making an attempt to replace CT with MRI in order to reduce cost for imaging studies and avoid possible radiation exposure [24–28]. In fact, some authors demonstrated that quantification using sagittal images of MRI is equally accurate with that of using 3DCT or 2DCT [24–26]. Owens and co-workers proposed a unique method of obviating use of CT using MRI [27]. They found that, although sexual difference was present, the relationship between the height and width was similar in sagittal images of MRI in normal shoulder. Therefore, the expected glenoid width can be easily estimated using glenoid height in patients with glenoid anteroposterior bone loss [27].

Fig. 4 Quantifying method of the glenoid bone loss. Percentage defect of the glenoid is defined as a ratio of defect width (**b**) against the diameter of the assumed inferior circle of the glenoid (**a**). With permission from Sugaya H. Chapter 14. Instability with bone loss. In: Angelo, Esch, Ryu, editors. AANA Advanced Arthroscopy: The Shoulder. Philadelphia: Elsevier; 2010. p.136–46. [10]

3DCT Is the gold standard

These studies may indicate that MRI could replace 2D- or 3DCT images if the role of preoperative imaging study was limited to quantification of glenoid bone loss. However, the role of preoperative imaging study is, first of all, to assess the glenoid shape and morphology in shoulders with recurrent anterior instability in addition to quantifying glenoid bone loss [4]. In this view, 3DCT is the most recommended preoperative imaging study for bony tissue which provides critical and substantial information of the glenoid [4, 29, 30•]. Rerko and colleagues estimated diagnostic accuracy by comparing 3DCT with 2DCT, radiography, and MRI using cadaveric specimen with native shoulders and 3 sequential anteroinferior defects, and concluded that 3DCT is the most accurate and reliable imaging modality followed by 2DCT [30•, 31].

Conclusions

Despite the cost and possible radiation exposure, 3DCT with humeral head digitally subtracted is the most recommended preoperative imaging study for bony tissue, which provides critical and substantial information of the glenoid in shoulders with recurrent anterior glenohumeral instability.

Compliance with Ethics Guidelines

Conflict of Interest Hiroyuki Sugaya receives payment from DepuySynthes and Smith & Nephew for development of education presentations including speakers' bureaus.

Human and Animal Rights and Informed Consent This article itself does not contain any studies with human or animal subjects performed by the author. In addition, the author's articles cited in this manuscript had cleared human and animal rights and obtained informed consent from all subjects.

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