J Shoulder Elbow Surg (2020) 29, 2668–2673

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

Intraoperative radiographic method of locating the radial head safe zone: the bicipital tuberosity view

Nathan Hoekzema, MD[a], Robert Gray, MD[b], Jorge Orbay, MD[c], Francisco Rubio, MD[c], Lauren Vernon, PhD[c], Allicia Imada, MD[d], Deana Mercer, MD[d,*]

[a]*Department of Orthopaedic Surgery, University of California, Fresno, CA, USA*
[b]*Department of Orthopaedic Surgery, NorthShore University HealthSystem, Chicago, IL, USA*
[c]*Miami Hand and Upper Extremity Institute, Miami, FL, USA*
[d]*Department of Orthopaedics & Rehabilitation, The University of New Mexico, Albuquerque, NM, USA*

Hypothesis: The proximal radius is asymmetrical, is mostly articular, and rotates through a large arc of motion. Because of these anatomic factors, there is limited space for hardware. This is magnified in the setting of complex fractures. The portion of the radial head where a radial head plate can be placed without compromising forearm motion has been termed the "safe zone." We hypothesized that the bicipital tuberosity could be used as a reproducible intraoperative fluoroscopic landmark to confirm radial head plate position in the safe zone.
Methods: Seventeen cadaveric radii were evaluated. First, the anatomic safe zone was identified using the method previously described by Caputo et al. A proximal radial plate was then placed in the center of this safe zone. The relationship of the plate to the tuberosity was evaluated, and the angle from the point of the greatest tuberosity profile to the center of the safe zone was measured.
Results: The maximum profile of the bicipital tuberosity is 166° ± 10° from the center of the safe zone as described by Caputo et al. By use of radiographic imaging, a radial head plate placed directly opposite the bicipital tuberosity will be within the safe zone. This position can be ascertained fluoroscopically with an anteroposterior view of the proximal forearm, in which the surgeon rotates the forearm into full supination. The plate should be placed opposite the bicipital tuberosity as seen on the greatest profile at maximum supination. With this method, the plate will be consistently placed within the safe zone.
Conclusion: The bicipital tuberosity can be used as a consistent radiographic anatomic landmark to ensure proximal radial plate placement within the safe zone. If the proximal radial head plate is placed 166° ± 10° opposite the bicipital tuberosity, a landmark easily identified on intraoperative imaging, the implant will be in the safe zone and will not impinge on the ulna in rotation.
Level of evidence: Anatomy Study; Cadaveric Dissection and Imaging

Keywords: Safe zone; bicipital tuberosity; PRUJ impingement; radiography; radial head fracture; radial head fixation

Institutional review board approval was not required for this anatomic study.

*Reprint requests: Deana Mercer, MD, Department of Orthopaedics & Rehabilitation, MSC10 5600, One University of New Mexico, Albuquerque, NM 87131, USA.

E-mail address: dmercer@salud.unm.edu (D. Mercer).

Radial head fractures are the most common fractures of the elbow in adults, with an incidence of approximately 3 per 10,000 persons per year.[4,7] These fractures most often occur after a fall onto an outstretched arm with the forearm pronated and the elbow slightly flexed.[3] The radial head transmits up to 60% of the direct axial load applied through

1058-2746/© 2020 The Author(s). This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
https://doi.org/10.1016/j.jse.2020.05.011

the wrist, and it stabilizes against valgus load and the medial collateral ligament.[8,9,13] Radial head fractures are often treated nonoperatively or with prosthetic replacement.[11] However, it is advised to perform open reduction–internal fixation of the radial head in displaced fractures of ≤3 fragments.[11,12] The fracture pattern on imaging, physical examination findings, and associated injuries can help guide treatment.[4,7]

During placement of a plate during open reduction–internal fixation of radial head and neck fractures, it can be difficult to discern the correct anatomic position that avoids implant impingement against the ulna at the proximal radioulnar joint (PRUJ) in forearm rotation (Fig. 1). The lateral aspect of the radial head has been described as the "safe zone" for implant placement.[1,14] This safe zone is an arc of approximately 110°, contains thin to no articular cartilage, and does not contact the proximal ulna at the PRUJ during pronosupination. The forearm—and thus the radial head—moves through an arc of motion of approximately 180°.[10,14,15] This nonarticular safe zone of the radial head is important because it provides a surface for placing implants that allows internal fixation of proximal radial fractures without interference with physiological motion.[1,6,14,15]

Various studies have evaluated different techniques to identify the safe zone.[1,14,16] In a cadaveric study, Smith and Hotchkiss[14] used a lateral approach to the elbow in which they marked horizontal lines on the radial head at neutral rotation, full pronation, and full supination. Caputo et al[1] used palpable landmarks on the distal radius (ie, radial styloid and Lister tubercle) to define a 110° arc that was then extrapolated proximally to the radial head. More recently, Zhan et al[16] used multiplanar reconstruction from axial computed tomography data to identify the safe zone. They recommended this computed tomography technique for evaluating postoperative malrotation to determine whether implant abutment is present. They do not recommend this technique for preoperative planning. These well-described methods of defining this anatomic proximal safe zone of the proximal radius[1,14,16] are useful. However, they can be difficult to apply in the operative setting with extremity edema, complex fractures, hematoma, and generalized disruption of the anatomy that limits exposure and the ability to rotate the forearm.

The bicipital tuberosity is a prominent and well-defined bony landmark. During surgical procedures on the radial head and neck, the bicipital tuberosity can be used via fluoroscopy to determine appropriate radial head plate placement without requiring excessive exposure. This view is called the "bicipital tuberosity view," and we hypothesized that it could be used as an easily obtainable and reproducible intraoperative image that (1) confirms radial head implant positioning within the safe zone, (2) avoids the complication of PRUJ impingement by proximal radial plate and screw constructs, and (3) corresponds to nearly perfect lateral placement of the radial head plate if centered within the safe zone. We aimed to define the safe zone by using established methods[1,14] and to compare this defined safe zone with the position of the bicipital tuberosity, which will be measured both on the radial head and on fluoroscopic imaging.

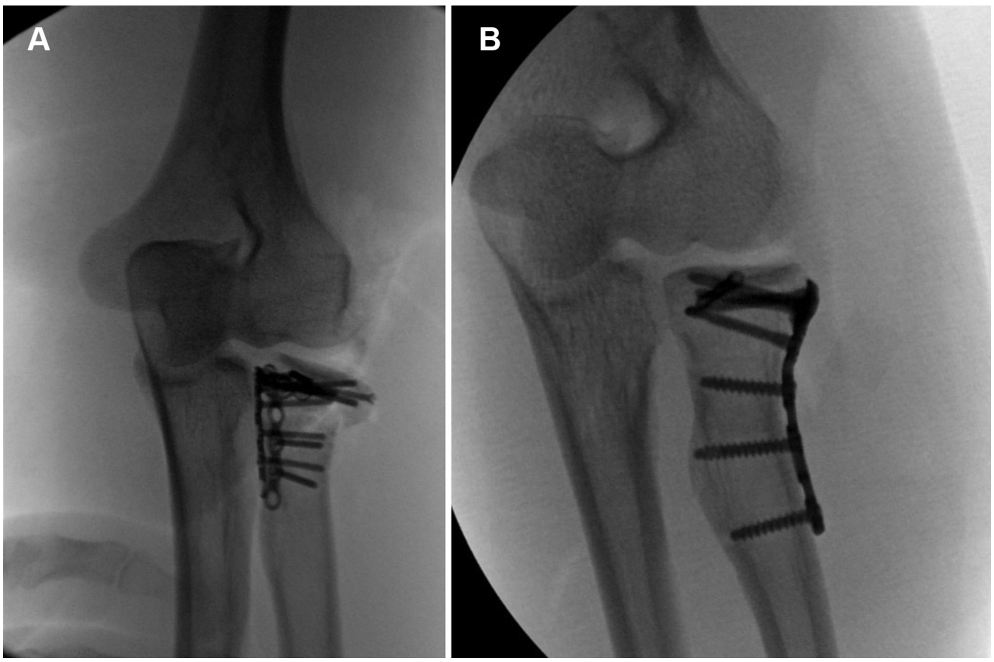

Figure 1 Radial head plate placement in proximal radioulnar joint causing impingement (**A**) and in safe zone (**B**). It should be noted that this correctly positioned plate is seen in profile while the bicipital tuberosity is positioned at its widest prominence.

Methods

We used the bicipital tuberosity as a radiographic anatomic landmark to ensure implant placement in the safe zone during plate fixation of radial head and neck fractures. Seventeen dry cadaveric radii were used: 15 right and 2 left specimens. The 2 left specimens were added to ensure that the method was consistent and reproducible on both the left and right radii.

Defining radial head anatomic safe zone

The safe zone was identified using the method described by Caputo et al.[1] Two distal landmarks (ie, radial styloid and Lister tubercle) were identified on each specimen. A line was extrapolated proximally from each of these distal landmarks and marked on the radial head. A straight edge was used to ensure consistency in markings across specimens. These markings defined the borders of the safe zone for radial head plate placement. A tape measure was used to measure along the approximately 110° defined safe zone arc to determine the amount of space available for radial head placement within the safe zone. The center of the safe zone was identified and marked for later plate placement.

Safe zone in relation to bicipital tuberosity

A K-wire was placed in the center of the radial head to define the position of the safe zone in relation to the bicipital tuberosity (Fig. 2, *A*). The radial head center was identified using a concentric circle goniometer as a guide, and the K-wire was placed in the center of the circle that fit the best (Fig. 2, *B*). The most prominent portion of the bicipital tuberosity was identified axially based on visual assessment. One arm of the goniometer was aligned with the most prominent portion of the bicipital tuberosity, and the other goniometer arm was aligned with the previously marked center of the safe zone. The angle between the 2 arms was then measured. This measurement was performed 3 times each by 3 different investigators, and the average was calculated.

Hardware placement in safe zone

After the safe zone was delineated using the method of Caputo et al,[1] the radial head plate was centered within this zone using standard technique. The precontoured plates (Skeletal Dynamics Protean Plates; Skeletal Dynamics, Miami, FL, USA) were placed 5 mm distal to the most proximal articular rim and secured with screws (Fig. 3, *A* and *B*).

Verifying adequacy of bicipital tuberosity view for assessing plate placement

The bicipital tuberosity view is a radiographic technique by which to evaluate radial head placement within the safe zone. The forearm was rotated into the most anatomically achievable supination, and the anteroposterior view of the elbow was obtained. In this position, the bicipital tuberosity was seen with the most prominent profile anatomically possible. To obtain this view, fluoroscopy was used with the plate positioned in the safe zone

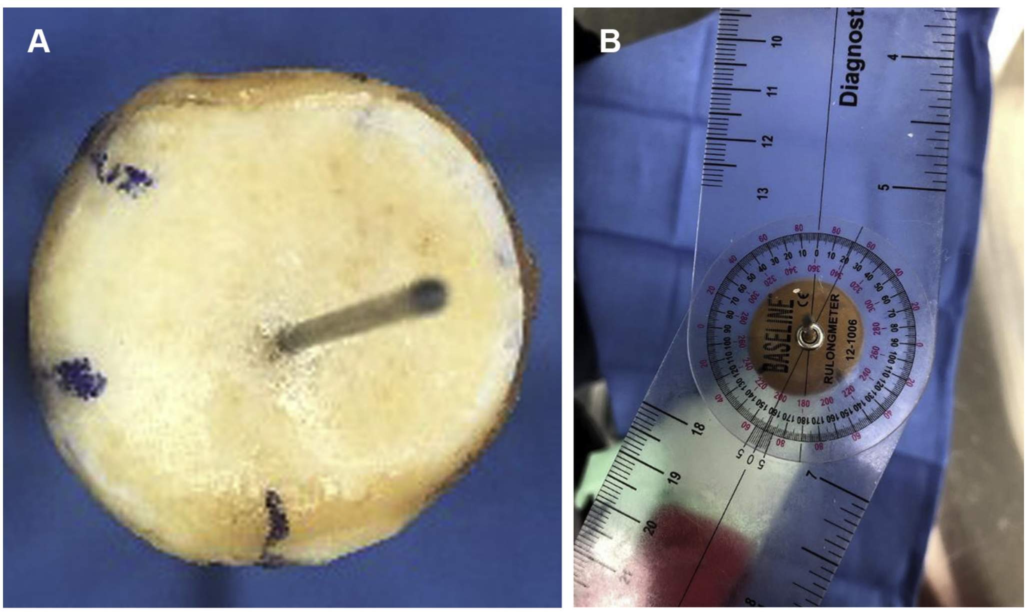

Figure 2 (**A**) Radial head end-on view showing safe zone. The K-wire is placed in the center of the radial head defined by aligning a best-fitting circle on the head of the radius and placing the K-wire in the center of the circle. The safe zone is shaded in *blue*. *1*, mark corresponding to radial styloid; *2*, mark corresponding to Lister tubercle; *3*, mark corresponding to center of safe zone; *4*, bicipital tuberosity. The safe zone is shaded in *blue*. (**B**) The goniometer is aligned with the most prominent portion of the bicipital tuberosity and center of the safe zone to quantify the relationship between the bicipital tuberosity prominence and the center of the safe zone.

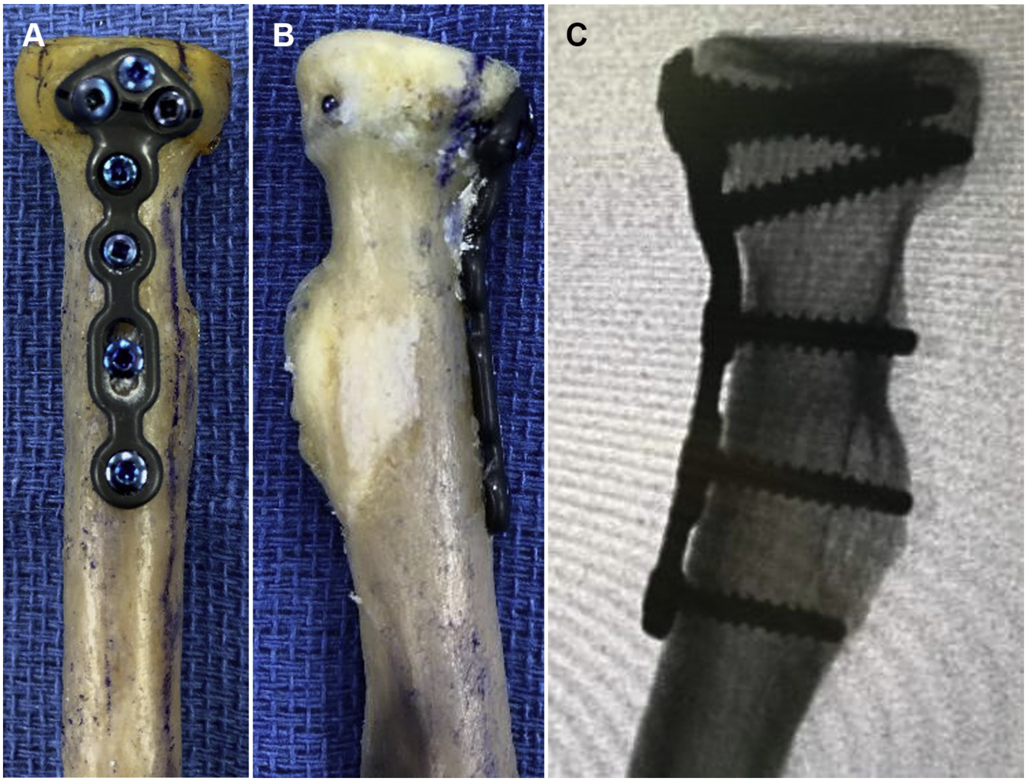

Figure 3 (**A**) Specimen showing radial head plate placement using anatomic landmarks described to maintain position in safe zone. The specimen shown is the smallest specimen in our series, with the smallest-sized safe zone. (**B**) The plate is opposite the bicipital tuberosity. (**C**) Fluoroscopic image showing bicipital tuberosity view. The proximal radius is rotated under fluoroscopy until the bicipital tuberosity is on the greatest profile. It should be noted that the plate, which is centered in the safe zone, is directly opposite the bicipital tuberosity as the image also shows perfect lateral placement of the plate.

(Fig. 3, C). The relationship of the plate to the bicipital tuberosity was noted.

Results

Safe zone definition

After using the method of Caputo et al,[1] we found the average width of the safe zone in our specimens to be 25 ± 4 mm (range, 16-31 mm). The maximum width of the radial head plate used in this study was 12.7 mm. Although the footprint of the plate within the safe zone varied depending on the size of the radial head, the radial head plate fit completely within this anatomically defined zone in all cases, with the plate occupying between 41% and 80% of the approximately 110° safe zone.

Safe zone in relation to bicipital tuberosity

We found the anatomic safe zone to be well defined using the bicipital tuberosity view and reproducible using bony anatomic landmarks (ie, radial styloid and Lister tubercle). The greatest profile of the bicipital tuberosity averaged 166° ± 10° to the center of the safe zone (Fig. 4).

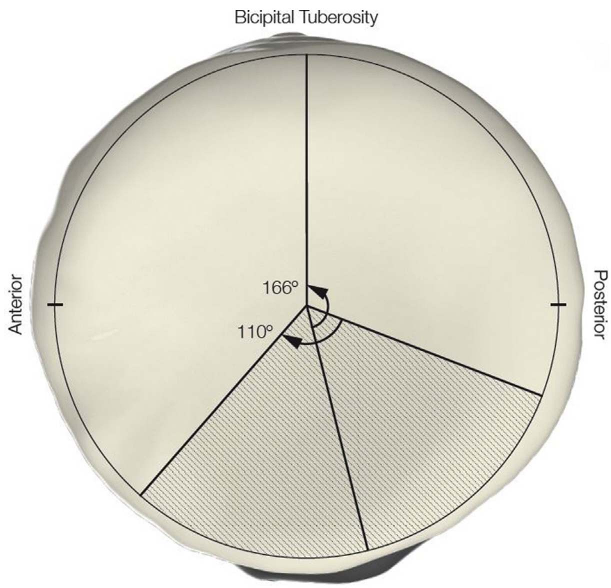

Figure 4 The radial head plate should be placed in the center of the previously defined 110° safe zone. Our measurements showed that the center of the safe zone is 166° from the greatest prominence of the bicipital tuberosity.

Table I Intraobserver agreement

Observer	ICC	Interpretation[5]
1	0.55	Moderate agreement
2	0.85	Good agreement
3	0.67	Moderate agreement

ICC, intraclass correlation coefficient.

Radiographic findings

In all cases, the plate was placed opposite the bicipital tuberosity. The bicipital tuberosity view yielded an image that showed (1) nearly perfect lateral placement of the radial head plate and (2) the bicipital tuberosity in its most anatomically achievable profile. Therefore, placing a radial head plate directly opposite the bicipital tuberosity is a reliable and reproducible method that ensures no hardware impingement at the PRUJ with forearm rotation.

Intraobserver and interobserver agreement

The intraclass correlation coefficient was calculated for both intraobserver and interobserver agreement. The calculations were performed with the R package "irr" and the function "icc" (R Foundation for Statistical Computing, Vienna, Austria). A 2-way model was used to test for agreement. Each observer measured the 17 specimens 3 times. Table I shows the results for the intraobserver calculations. For interobserver agreement of the averages from each observer, the intraclass correlation coefficient was calculated to be 0.76, which indicates good agreement.[5]

Discussion

Radial head fractures are common injuries, and appropriate treatment is important to minimize pain, maintain elbow stability, and maximize forearm range of motion. Due to the nearly 180° of forearm pronosupination, the radial head safe zone is a small target and can be difficult to identify intraoperatively.[2] The anatomic landmarks described (ie, radial styloid and Lister tubercle) can be difficult to identify in traumatic injuries owing to swelling, body habitus, and lack of visibility on intraoperative views of the fracture and hardware.

The bicipital tuberosity is an easily identifiable landmark that can be used to identify the radial head safe zone. In the operating room, fluoroscopy can be used to identify the bicipital tuberosity and may be useful in cases in which the radial styloid and Lister tubercle are obscured by trauma, swelling, and body habitus.

There were some limitations to this study. Isolated radii were used, which limited us to using the method of Caputo et al[1] as the control method of determining the safe zone. The method of Smith and Hotchkiss[14] could not be described in the absence of the PRUJ. Cadaveric specimen quantity was limited; however, a sample size of 17 radii is comparable to the sample sizes of other published studies and was deemed sufficient to account for variations in anatomy. We used 1 commercially available radial head plate and did not compare it with other implants. Other radial head plates with increased plate width may present a narrower margin of error because they would cover a larger portion of the width of the safe zone.

Conclusion

The bicipital tuberosity view may be useful in confirming appropriate placement of a radial head plate in the anatomic safe zone of the radial head. The center of the safe zone is 166° from the highest point of the tuberosity, and plates placed within 15° of this central point were reliably and completely in the safe zone. This knowledge will prove useful not only when placing a plate on a reduced radial head fracture but also for appropriately reducing radial head fragments in the proper rotation with respect to the radial shaft. It should be noted that radial head plates wider than the 12.7-mm maximum width of the implant used in this study will lower the tolerance and require more attention to placing the plate exactly in the center of the safe zone. The bicipital tuberosity view is a useful adjunct to nonradiographic landmarks in determining appropriate hardware placement and avoiding complications related to plate malpositioning.

Acknowledgments

The authors thank Angelique Tapia for editorial assistance.

Disclaimer

All work was conducted at the Miami Hand & Upper Extremity Institute, using its equipment and materials.

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

References

1. Caputo AE, Mazzocca AD, Santoro VM. The nonarticulating portion of the radial head: anatomic and clinical correlations for internal fixation. J Hand Surg Am 1998;23:1082-90.
2. Giannicola G, Manauzzi E, Sacchetti FM, Greco A, Bullitta G, Vestri A, et al. Anatomical variations of the proximal radius and their effects on osteosynthesis. J Hand Surg Am 2012;37:1015-23. https://doi.org/10.1016/j.jhsa.2012.02.005
3. Jackson JD, Steinmann SP. Radial head fractures. Hand Clin 2007;23: 185-93. vi. https://doi.org/10.1016/j.hcl.2007.01.009
4. Kaas L, van Riet RP, Vroemen JP, Eygendaal D. The epidemiology of radial head fractures. J Shoulder Elbow Surg 2010;19:520-3. https://doi.org/10.1016/j.jse.2009.10.015
5. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. J Chiropr Med 2016; 15:155-63. https://doi.org/10.1016/j.jcm.2016.02.012
6. Kuhn S, Burkhart KJ, Schneider J, Muelbert BK, Hartmann F, Mueller LP, et al. The anatomy of the proximal radius: implications on fracture implant design. J Shoulder Elbow Surg 2012;21:1247-54. https://doi.org/10.1016/j.jse.2011.11.008
7. Mason ML. Some observations on fractures of the head of the radius with a review of one hundred cases. Br J Surg 1954;42: 123-32.
8. Morrey BF, An KN, Stormont TJ. Force transmission through the radial head. J Bone Joint Surg Am 1988;70:250-6.
9. Morrey BF, Tanaka S, An KN. Valgus stability of the elbow: a definition of primary and secondary constraints. Clin Orthop Relat Res 1991:187-95.
10. Ries C, Muller M, Wegmann K, Pfau DB, Muller LP, Burkhart KJ. Is an extension of the safe zone possible without jeopardizing the proximal radioulnar joint when performing a radial head plate osteosynthesis? J Shoulder Elbow Surg 2015;24:1627-34. https://doi.org/10.1016/j.jse.2015.03.010
11. Ring D. Radial head fracture: open reduction-internal fixation or prosthetic replacement. J Shoulder Elbow Surg 2011;20(Suppl):S107-1012. https://doi.org/10.1016/j.jse.2010.11.011
12. Ring D, Quintero J, Jupiter JB. Open reduction and internal fixation of fractures of the radial head. J Bone Joint Surg Am 2002;84-A:1811-5. https://doi.org/10.2106/00004623-200210000-00011
13. Schneeberger AG, Sadowski MM, Jacob HA. Coronoid process and radial head as posterolateral rotatory stabilizers of the elbow. J Bone Joint Surg Am 2004;86-A:975-82. https://doi.org/10.2106/00004623-200405000-00013
14. Smith GR, Hotchkiss RN. Radial head and neck fractures: anatomic guidelines for proper placement of internal fixation. J Shoulder Elbow Surg 1996;5(Pt 1):113-7.
15. Weiss AP, Hastings H II. The anatomy of the proximal radioulnar joint. J Shoulder Elbow Surg 1992;1:193-9.
16. Zhan Y, Luo CF, Chen YJ. A new method to locate the radial head “safe zone” on computed tomography axial views. Orthop Traumatol Surg Res 2018;104:71-7. https://doi.org/10.1016/j.otsr.2017.10.013