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ORIGINAL PAPER

Anterior radial head subluxation in primary elbow osteoarthritis

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Abstract

Purpose To investigate elbows with primary osteoarthritis (OA) for the presence of anterior radial head subluxation.

Methods A total of 71 patients with elbow osteoarthritis and 45 with lateral epicondylitis were initially identified. The baseline characteristics and preoperative elbow X-rays of consecutive patients that had been clinically confirmed with elbow OA or lateral epicondylitis between March 2011 and January 2020 were then retrospectively reviewed. The radiocapitellar ratio (RCR; the ratio of the displacement of the radial head about the diameter of the capitulum) was calculated using lateral views. These RCR values were compared between the OA and lateral epicondylitis cases.

Result A significant increase was detected in RCR values between patients in elbow OA and the control group (13.2% (± 10.6) vs −1.2% (± 6.8), $P<0.001$). Based on receiver operating characteristic curves, RCR values had an excellent area under the curve (0.89) for the detection of elbow OA (Youden index, 0.69; sensitivity, 89%; specificity, 80%). Based on the ROC curve, the cutoff value of RCR was 0.04. Patients with RCR ≥ 0.04 had a significantly higher proportion of cases with elbow OA (risk ratio, 31.50 [95% CI, 11.17–88.82]) than those with RCR ˂ 0.04 (P ˂ 0.001).

Conclusion Radial head subluxation is a radiographic finding associated with elbow OA and RCR ≥ 0.04 could be used as an aetiological factor for elbow OA diagnosis.

Keywords Elbow osteoarthritis · Subluxation · Radiocapitellar ratio · Radial head

Introduction

Elbow osteoarthritis (OA) is a common joint disease and a major cause of disability. Genetics, ethnicity, aging, and an unbalanced joint loading due to instability or poor alignment have all been reported to be related to this condition. Many factors contribute to an unbalanced elbow joint loading, including interosseous membrane injury [13], ligament tears [9], and joint incongruity [6].

Another factor leading to impaired load transmission and elbow OA that is less commonly discussed is radial head subluxation. Over recent decades, the radial head has become increasingly recognized as an important stabilizer of the elbow [20]. It has also been suggested that the radial head engages the capitellar incongruity in positions of loading [32]. Another previous study reported that 57% and 43% of the axial load was transmitted through the radiocapitellar and ulnotrochlear joints, respectively [8]. Elbow OA is proposed to initially develop on the lateral side [1, 10], and symptomatic RC osteoarthritis can remain undetected radiographically unless arthroscopy is performed [22]. Radial head subluxation is thus a potentially important radiographic

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finding but little has been published regarding this phenomenon in elbow OA. Furthermore, the mainly used elbow OA grading radiographic systems at present, including the classifications developed by Broberg and Morrey [3] and Jeon and Kwak [17], assess the severity of OA based on osteophyte formation and joint space narrowing and do not take account of radiocapitellar joint or radial head subluxation.

The purpose of this study was to investigate the presence of radial head subluxation in patients with elbow OA and whether the degree of subluxation could predict elbow OA existence. We hypothesized that radial head subluxation could be found in primary elbow OA and be predictive for elbow OA detection.

Methods

Approval from the Institutional Review Board was obtained (No. 2022-0696). The medical data of patients who were clinically confirmed with elbow OA and lateral epicondylitis at our single centre between March 2011 and January 2020 were retrieved. All patient data retrieved from the medical records and preoperative radiographic archives were retrospectively reviewed and the radiographs were taken immediately before surgery. All patients who underwent arthroscopic osteocapsular arthroplasty were enrolled as the OA group. The indications for arthroscopic osteocapsular arthroplasty were as follows: (1) patient had confirmed primary elbow osteoarthritis; (2) patients suffered from symptoms including pain, limited range of motion (defined as less than functional ROM) with or without concomitant ulnar neuropathy; and (3) patients had no improvement in symptoms with conservative treatment for six months [16]. As it is unethical to take radiological examinations on normal patients in the current centre. In addition, radiocapitellar ratio, indicating radial head translation, was found to have no differences in elbow sides, gender, and age [24]. Lateral epicondylitis is thought to be caused by soft tissue pathology at the origin of the elbow extensor tendons [31]. As a result, it does not cause biomechanical changes in the elbow joint and has nothing related to radiocapitellar alignment. Therefore, patients with lateral epicondylitis confirmed without arthritic changes on radiographs were enrolled as the control group for the comparison of subluxation of radial head between OA and non-OA elbows. All patients in the control group underwent arthroscopic extensor carpi radialis brevis. All the surgeries in our patient cohort had been conducted by the same senior surgeon (I.H.J.) and all patients underwent an X-ray examination before surgery. Three patients without a standard lateral view X-ray were excluded, including one in the OA group and two in the control group. A final cohort of 71 patients with elbow OA (56 male, 15 female) was included along with 45 lateral epicondylitis (15 male, 30 female) cases as the control group.

Measurement of imaging parameters

We reviewed the baseline data and radiographic parameters for our study patients. The method of measuring RC joint translation was termed the radiocapitellar ratio (RCR) measurement, which has already been well documented as a valid and reliable parameter in both healthy and arthritis elbows in previous reports [4, 24] (Fig. 1). The radiocapitellar ratio was defined as the ratio of the displacement of the radial head (D_{RH}) about the diameter of the capitellum ($Ø_{capitellum}$) as follows [24]:

$$RCR_{\%} = D_{RH}/Ø_{capitellum}$$

RCR was measured using the lateral views of the patients' elbows. A positive RCR value indicated anterior radial head translation, while a negative RCR result signified a posterior radial head translation. All measurements were conducted by an orthopaedic surgeon (H.B) and a radiologist (C.H.Z) who did not participate in the surgeries.

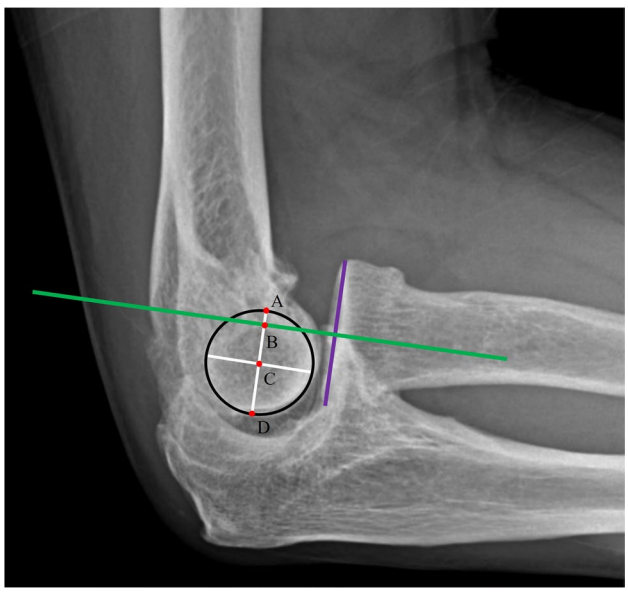

Fig. 1 Measurement of the preoperative radiocapitellar ratio. The purple line marks the articular surface of the radial head. The green line is drawn perpendicular to the articular surface of the radial head at its middle distance. The articular radius of curvature of the capitellum is used to resolve the indicated black circle with the diameter equal to $Ø_{capitellum}$ (AD). The minimal distance is measured between the right bisector of the radial head and the center of the capitellum (D_{RH} = BC). The ratio is then the minimal distance between the right bisector of the radial head and the center of the capitellum (BC), divided by the diameter of the capitellum (AD)

Statistical analyses

An unpaired *t* test was used to compare the demographic data and the radiocapitellar ratios between the patients with elbow OA and lateral epicondylitis. The chi-square test was used to detect differences between binary variables. These statistical analyses were conducted using SPSS 24.0 software (IBM, NY, USA). Subsequently, the predictive validity of RCR was assessed by use of receiver operating characteristic (ROC) curve statistics. AUC ≥ 0.7 was considered acceptable and AUC ≥ 0.8 was considered excellent [2]. The significance level was set at $P < 0.05$.

Post hoc power analysis

G*Power 3 statistical analysis software package was used to perform the power analysis. The effect sizes were 1.62 for RCR values by defining the sample size as 71 in the OA group and 45 in the control group. The level of significance (α) was set as 0.05. The results showed that current sample size provided 80% power (1 - β =0.8; $\alpha = 0.05$) to detect significant difference in RCR values between two groups.

Results

A total of 116 patients, including 71 patients in the OA group and 45 patients in the control group, were included in this study. Patient demographics and surgical-related variables are reported in Table 1. Significant differences were detected in age and sex ($P = 0.001$ and $P = 0.042$. respectively).

The ICC index of intraobserver and interobserver reliability for the RCR value were 0.92 and 0.81, respectively. The control group (Fig. 2A) was presented with mean RHR of −1.2% (± 6.8) of the capitellum. The OA group was presented with mean RHR of 13.2% (± 10.6) of the capitellum. Significant increases were noted in the RCR of patients with elbow OA compared with the control group cases ($P <$ 0.001; Table 2, Fig. 3).

Table 1 Comparison of the baseline characteristics between the study groups

Preoperative values	OA	Control	*P* value
No. of cases	71	45	-
Age, yr	56.6 ± 7.7	51.7 ± 7.8	0.001
Sex, male/female	56/15	15/30	0.042
Affected side, R/L	56/15	29/16	0.027
Symptom duration	30.1 ± 41.0	22.2 ± 19.7	0.168

OA, osteoarthritis; yr, year; R, right; L, left

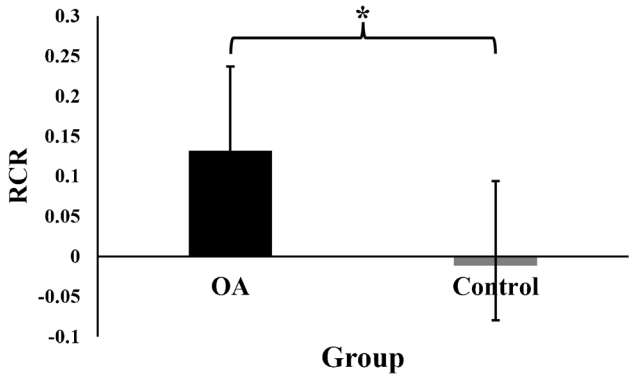

Fig. 2 RCR in elbow OA group (**A**) and control group (**B**); RCR, radiocapitellar ratio; OA, osteoarthritis

For determining the predictive value of RCR value on detection of elbow OA, the ROC curve was calculated. The RCR had an excellent predictive ability for OA detection (area under the ROC curve, 0.89; 95% CI, 0.82–0.95, $P <$ 0.001) (Fig. 4). A cutoff level of ≥ 0.04 (Fig. 5) was used to determine the OA existence (Youden index, 0.69; sensitivity, 89%; specificity, 80%).

All the cases were grouped according to the cutoff value; 63 and 9 patients were found to have a RCR ≥ 0.04, indicating larger anterior subluxation, in the OA and the control groups, respectively. By using the cutoff values to categorize patients, we found that the proportion of cases with elbow OA was significantly higher in cases with RCR ≥ 0.04 (risk ratio, 31.50 [95% CI, 11.17–88.82]) than those with RCR < 0.04 ($P <$ 0.001, Fig. 6).

Discussion

The most important finding of this study was that a significant increase in the RCR was detectable in OA elbows compared to those in the control group. Our results thus suggest that radial head subluxation could be found in most of the patients with elbow OA, and RCR could be used for OA detection. According to the results, patients who have RCR ≥ 0.04 should be treated carefully because they had 31.50 times higher risk of OA existence. Studies with larger cohorts are emerged to verify this cutoff value.

Table 2 Radiocapitellar ratio on lateral radiograph

	OA	Control	*P*
Mean (± SD)	0.13 ± 0.11	−0.01 ± 0.69	< 0.001
Range (MIN, MAX)	−0.12, 0.47	−0.15, 0.13	-

SD standard deviation, *MIN* minimum, *MAX* maximum, *OA* osteoarthritis

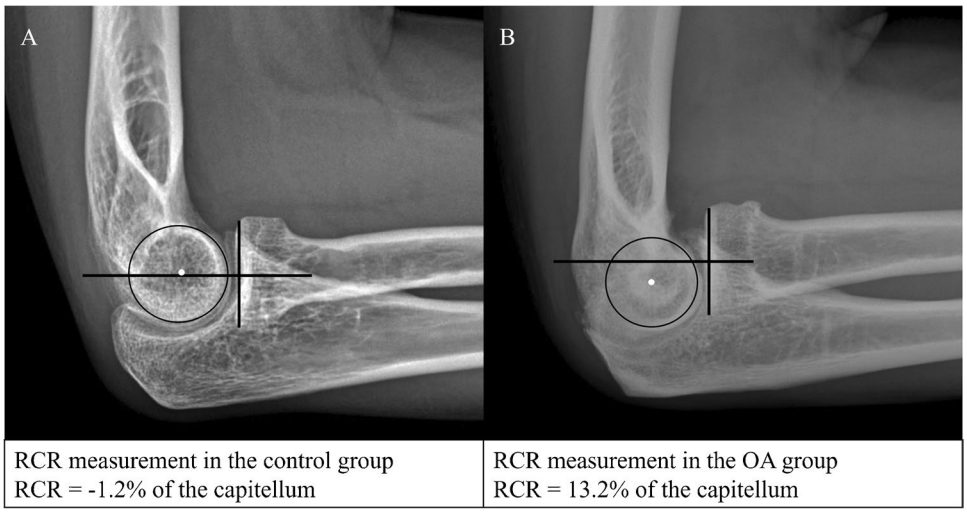

Fig. 3 Comparison of the RCR between the OA and Control groups. RCR, radiocapitellar ratio; OA, osteoarthritis

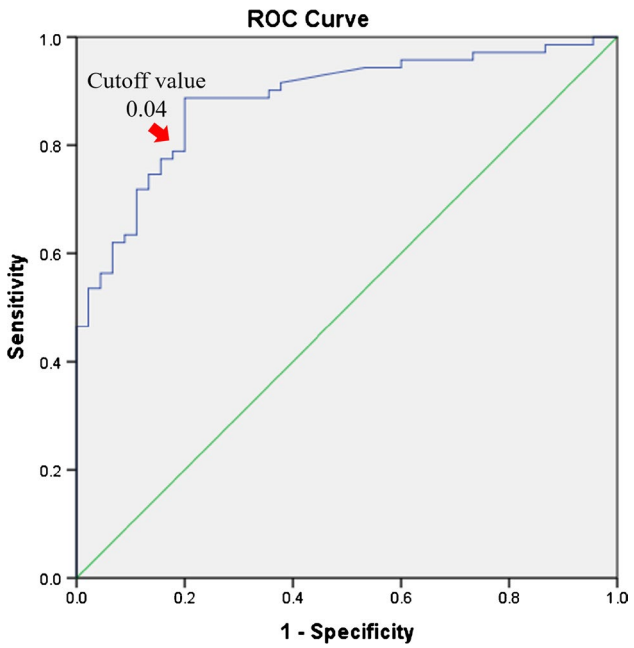

Fig. 4 Receiver operating characteristic (ROC) curve for the RCR value for predicting elbow OA; RCR, radiocapitellar ratio; OA, osteoarthritis

As it was not ethical to take an X-ray examination for the opposite side or healthy patients in the current centre, patients with lateral epicondylitis who confirmed with no arthritic changes on radiographs and under arthroscopy were included for the comparison of radial head subluxation between OA and non-OA elbows. Significant differences in age, sex, affected side, and BMI were detected between OA and non-OA patients. However, a previous study had proved that there was no difference in radiocapitellar ratio regarding the elbow side, sex, and age [24]. As a result, it was proposed that the differences in demographics would not affect the credibility of the results.

Malalignment of the upper limb has been regarded as being responsible for changes in the force distribution across the elbow joint and is thought to be a biomechanical factor associated with elbow OA [12]. Subluxation or incongruity of the RC joint can also induce cartilage shear and degeneration [23], which is related to the progression of elbow OA. Several biomechanical studies have described the importance of the radial head for restoring the complex articular movements of the elbow [5, 21, 30]. Maintenance of the radial head is also beneficial to load sharing of forces across the elbow joint. It has been demonstrated that tissues around normal elbow joint are stressed to similar levels as that of the lower limb [14]. It was proposed that elbow malalignment was associated with occurrence of osteoarthritis [12], much alike the lower extremity [7]. Lower limb malalignment has been demonstrated to be associated with progression of OA [26, 29]. Khamaisy et al. proposed that tibiofemoral subluxation in knee OA may be caused by the inherent laxity of the soft tissue around the knee [15]. Our data suggests that radiocapitellar subluxation is a radiographic finding associated with elbow OA occurring. However, malalignment is an ongoing and consistent process throughout all the stages of OA, which may lead to OA progression. Retting found that patients with advanced OA showed static anterior subluxation of the radial head and the authors believed that radiocapitellar joint was subjective to shear force when repetitive forceful loading was applied [23]. Zigarella et al. found that repetitive stress or shear force to the radiocapitellar joint contributed to progressive stretching and elongation of the annular ligament, which was associated with a relative hypermobility of the radial head [33]. It was proposed that radial head subluxation was likely to occur during the early phase because of the repetitive stress or shear force applied to the radiocapitellar joint. As it was reported that malalignment of the upper limb was associated with the

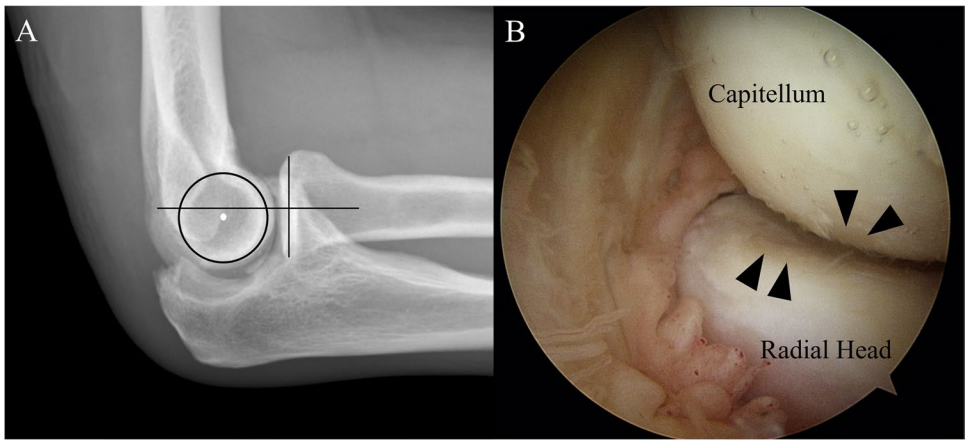

Fig. 5 **A** A patient with elbow OA showed RCR = 4% of the capitellum on lateral view of X-ray. **B** an Arthroscopic image shows early OA changes, including cartilage degeneration and wear of the capitellum and radial head (black arrowheads); RCR, radiocapitellar ratio; OA, osteoarthritis

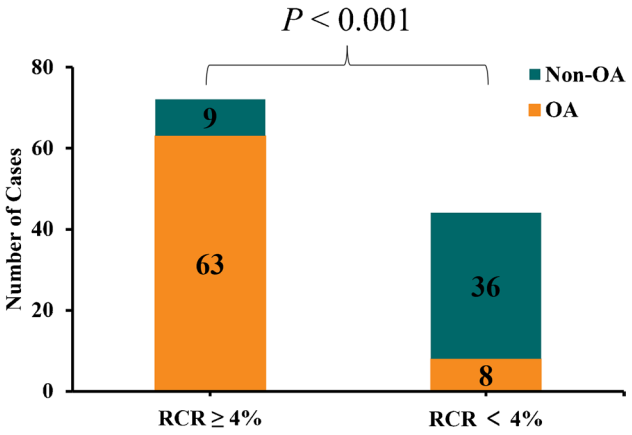

Fig. 6 The proportion of cases with elbow OA when grouped by RCR; OA, osteoarthritis; RCR, radiocapitellar ratio

distribution of forces transmitted across the elbow joint [12], it seemed reasonable to assume that the subluxation of radiocapitellar joint may also contribute to the loading change and OA progression. This was consistent with Retting et al.'s proposal that subluxation or dynamic instability of the radiocapitellar joint could be the initiator of progressive primary elbow OA and persistent subluxation or dynamic subluxation could induce cartilage fragmentation through shearing forces [23]. This may provide a radiographic indicator for early detection of primary elbow OA. Furthermore, aging was reported to contribute to the development of OA [12]. However, Richard et al. found that the development of OA caused by aging was because the joint became more susceptible to other OA risk factors [18]. Further study needs to be conducted to investigate the relationship between radiocapitellar subluxation and severity of elbow OA to reveal the clinical consequences associated with this finding.

A previous case report has suggested that the persistence of symptoms of the radiocapitellar joint is due to either the high stresses across the radial capitellar joint, resulting in OA, or malalignment of the radiocapitellar joint [11]. It has been further demonstrated that patients with elbow OA and radial head subluxation have inferior clinical outcomes after surgery and emphasized that an assessment of possible radiocapitellar degenerative changes in patients with primary OA of the elbow is an important intervention [23]. The radial head plays an important role in effective load transfer at the elbow [8]. Subluxation or incongruity of the RC joint will continue to induce cartilage shear and degeneration [23] and need to be carefully treated.

Lateral radiographs are used to detect mismatched articular surfaces and thereby detect subluxations of the elbow. Many tools have been developed to gauge radial head subluxations, including the radiocapitellar line (RCL) for elbows in children [27] and the radiocapitellar ratio (RCR) for an adult elbow [24]. It has been shown that a deviated laterality of the elbow, visible on a radiograph, could induce measurement errors when using the RCL method [19, 28]. Nevertheless, it is very difficult to obtain reliable bony landmarks in patients with elbow OA via an X-ray. However, RCR has been commonly employed to detect the radial head subluxation in patients with advanced arthritis after a total elbow arthroplasty, and it has also been proven to show good inter- and intra-rater reliability [4]. In a previous study, the RCR of a normal elbow was reported to be 4% and 95% of the cohort examined showed an RCR range of between −5 and 13%. An RCR value outside this range may therefore represent misalignment of the RC joint [24]. In this study, the mean RCRs of the OA group and control group were 13% and −1%, respectively. Still, the cutoff value of RCR is 0.04, which corresponds to the RCR of a normal elbow. This cutoff value may be applicable in the detection of elbow OA.

There were some limitations of note in our present study. First, the contralateral side of the patients with elbow OA could not be set as the control group because it is regarded as neither reasonable nor ethical to take an X-ray of a

normal elbow at our medical centre. Elbow with lateral epicondylitis was not a normal elbow for its soft tissue pathology; however, it does not cause biomechanical changes in the elbow joint. Second, the radiographic characteristics were not correlated with the clinical outcomes, which will be a focus of future studies. Third, the severity of radial head subluxation at varying stages of elbow OA was not assessed. However, the aim of this study was to detect the presence of radial head subluxation as a common radiographic finding in elbow OA. Further investigations of the correlation between radial head subluxation and the severity of elbow OA need to be conducted. Fourth, the absence of age-matched controls does not allow investigation of normal change over time as a "normal age-related" radial head subluxation. Fifth, bias may exist when we measure RCR values for patients with severe OA because of difficulties with pronation/supination. However, Sandman et al. have demonstrated that there is no difference in RCR values between the positions of the forearm in pronation and in supination at 90-degree flexion. Also, no difference was found between the positions of elbow flexion at 90-degree and maximal extension [25].

Conclusion

Overall, radial head subluxation is a radiographic finding associated with elbow OA and RCR ≥ 0.04 could be used as an aetiological factor for elbow OA diagnosis.

Author contributions Hui Ben: conceptualization, investigation, methodology, writing—original draft

Jae-Man Kwak and Chu Hui Zeng: data curation, methodology, writing—review and editing

Kyoung-Hwan Koh: supervision, visualization, writing—review and editing

In-Ho Jeon: conceptualization, methodology, project administration, supervision, writing—review and editing

Declarations

Institutional Review Board approval number 2022-0696

Consent to participate Not applicable.

Consent for publication Not applicable.

Conflict of interest The authors declare no competing interests.

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