

Reliability of radiographic measurement of lateral capitellohumeral angle in healthy children

Masaki Hasegawa, MD^a, Taku Suzuki, MD, PhD^{a,b,*}, Takashi Kuroiwa, MD^a, Yusuke Oka, MD^a, Atsushi Maeda, MD^a, Hiroki Takeda, MD^a, Kanae Shizu, MD, PhD^a, Takashi Tsuji, MD, PhD^{a,b}, Katsuji Suzuki, MD, PhD^a, Harumoto Yamada, MD, PhD^a

Abstract

This retrospective cohort study was designed to validate the reliability of measurement of the lateral capitellohumeral angle (LCHA), an index of sagittal angulation of the elbow, in healthy children. The results were compared to the Baumann angle (BA), which is a similar concept to LCHA.

Sixty-two radiographs of the elbow in healthy children (range, 2–11 years) were reviewed by 6 examiners at 2 sessions. The mean value and reliability of the measurement of LCHA and BA were assessed. Intraobserver reliability and interobserver reliability were calculated using intraclass correlation coefficients (ICCs).

The mean LCHA value was 45° (range, 22° to 70°) and the mean BA was 71° (range, 56° to 86°). The ICCs for intraobserver reliability of the LCHA measurements were almost perfect for 2 examiners, substantial for 3 examiners, and moderate for 1 examiner with a mean value of 0.77 (range, 0.57–0.95). For BA measurements, the ICCs were almost perfect for 1 examiner and substantial for 5 examiners with a mean value of 0.74 (range, 0.66–0.83). The ICCs for interobserver reliability between the first and second measurements were both moderate for LCHA (0.56 and 0.51) and for BA (0.52 and 0.50).

LCHA showed almost the same reliability in measurement as BA, which is the gold standard assessment for coronal alignment of the elbow. LCHA showed moderate-to-good reliability in the evaluation of sagittal plane elbow alignment.

Abbreviations: BA = Baumann angle, CA = carrying angle, CI = confidence interval, HEWA = humerus-elbow-wrist angle, ICC = intraclass correlation coefficient, LCHA = lateral capitellohumeral angle.

Keywords: Baumann angle, interobserver reliability, intraobserver reliability, lateral capitellohumeral angle, lateral humerocapitellar angle, reliability

1. Introduction

Various radiographic parameters of the elbow have been used for the evaluation of surgical treatment of pediatric elbow fractures or other disorders. Humerus-elbow-wrist angle (HEWA), carrying angle (CA), and Baumann angle (BA) in the coronal plane, or shaft condylar angle, humerocapitellar angle, anterior humeral line, and coronoid line in the sagittal plane commonly have been used to assess angular deformity of the elbow.^[1–3] Recently, the intraobserver reliability and interobserver reliability of HEWA, CA, and BA measurements have been demonstrated.^[2–7] On the contrary, limited data are available to assess the reliability of measurements of radiographic parameters in the sagittal plane.^[2,5,8]

An index of sagittal angulation of the elbow termed shaft condylar angle, lateral humerocapitellar angle, humerocapitellar angle, or humerocondylar angle has been reported.^[11,9] In 2011, Shank et al introduced the lateral capitellohumeral angle (LCHA), which is the angulation between the humeral shaft and capitellum in the pediatric elbow.^[5] They demonstrated the reliability of measurement of LCHA in 71 normal elbows by 5 testers, and its reliability was inferior to that of BA. The BA measurement showed excellent intraobserver (correlation coefficient 0.86) and interobserver (0.80) reliability, while LCHA showed good intraobserver (0.67) and fair interobserver (0.37) reliability. They concluded that LCHA is not a reliable tool to assess radiographic outcomes by multiple examiners and further research is needed to better define sagittal plane angular deformities. Nevertheless, LCHA gradually has been adopted for the assessment of sagittal radiographic parameters of the elbow in recent years.^[1,10–12]

The purpose of this retrospective cohort study was to validate the reliability of measurement of LCHA in healthy children. To confirm the reliability of LCHA, the results were compared to BA, which is similar in concept to LCHA and is the standard assessment for axial angulation of the elbow.

2. Materials and methods

This study protocol was approved by our institutional review board. From April 2007 to December 2015, 75 patients who underwent surgical treatment for supracondylar fracture of the humerus were retrospectively enrolled at our single institution, which specializes in trauma surgery. According to the protocol of

Editor: Sebastian Farr.

The authors have no funding and conflicts of interest to disclose.

^a Department of Orthopaedic Surgery, Fujita Health University, Dengakugakubo, Kutsukake, Toyoake, Aichi, ^b Department of Orthopedic Surgery, Keio University School of Medicine, Shinjuku, Tokyo, Japan.

* Correspondence: Taku Suzuki, Department of Orthopedic Surgery, Keio University School of Medicine, 35 Shinano-machi, Shinjuku, Tokyo 160-8582, Japan (e-mail: sutaku49@gmail.com).

Copyright © 2018 the Author(s). Published by Wolters Kluwer Health, Inc.

This is an open access article distributed under the Creative Commons Attribution-NoDerivatives License 4.0, which allows for redistribution, commercial and non-commercial, as long as it is passed along unchanged and in whole, with credit to the author.

Medicine (2018) 97:14(e0314)

Received: 16 October 2017 / Received in final form: 2 March 2018 / Accepted: 9 March 2018

<http://dx.doi.org/10.1097/MD.00000000000010314>

our hospital, radiographs of the uninjured elbow were taken at initial injury because accurate diagnosis of pediatric elbow fractures is sometimes difficult due to presence of the capitellar physis. These normal radiographs were reviewed for this study. Only patients <12 years of age were included because the capitellar physis is closed in some patients over 13 years and measurement of LCHA and BA is difficult.^[1] Exclusion criteria included patients with previous trauma or flexion contracture of the uninjured elbow, congenital disorders, or unavailable radiographs of the uninjured side. Exclusion criteria of the previous study were adapted for this study: radiographs that did not include coronal landmarks needed for measurement were excluded.^[3] A senior resident (MH), who did not participate in the measurement, reviewed medical records and radiographs of the 75 patients and enrolled radiographs according to the criteria.

All radiographs were reviewed independently by 6 orthopedic surgeons with different years of experience in our single institution. The group included 2 hand specialists (KS and TS), 2 senior residents (TK and YO), and 2 junior residents (AM and HT). The postgraduate experience of orthopedic surgeons in this group was 23 and 13 years of the 2 hand specialists (observers 1 and 2), 8 and 6 years of the 2 senior residents (observers 3 and 4), and 3 years of the 2 junior residents (observers 5 and 6). Observers were informed that normal radiographs had been obtained from the uninjured elbow of the patients with supracondylar fracture of the humerus. The imaging review was repeated twice in the same manner at an interval of 4 weeks in a blinded fashion. Data of other reviewers were also blinded to each reviewer for all measurements.

2.1. Measurement method of radiographic parameters

During the research period, anterior and lateral radiographs were taken by about 30 radiographers. To ensure lateral positioning of the elbow, all of the radiographs were made in a standard manner, without the use of sedation, with the patient sitting in a chair with elbows in 90° of flexion and the forearm in supination. Anteroposterior radiographs were made with the patient sitting in a chair with the arm in full extension and with the forearm in supination. A senior resident (MH) selected radiographs for review and input the identification numbers of the radiographs into computer software (Excel 2010; Microsoft, Redmond, WA). These data were made available to each observer and were used to generate digital radiographic images that were then stored in a picture archiving and communication system in our hospital. Digital electrogoniometers linked to a computer were used for angular measurements (Rapideye Core, Toshiba Medical Systems Corporation, Ohtawara, Japan). To ensure that all evaluations were completed in the same manner, a senior resident (MH) explained to all the reviewers before measurement how to measure each parameter.

2.1.1. Lateral capitellohumeral angle. This is the angle between the line along the anterior border of the distal humeral shaft and a line along the open capitellar physis on the lateral radiographs (Fig. 1).^[5]

2.1.2. Baumann angle. This is the angle between the longitudinal axis of the humeral shaft and a line along the open capitellar physis on the anteroposterior radiographs. A longitudinal axis of the humeral shaft was determined by a line connecting the midpoints of 2 transverse lines (1 proximal and 1 distal) across the humerus that connected the medial and lateral cortices (Fig. 2).^[1,2,5]



Figure 1. Lateral capitellohumeral angle.



Figure 2. Baumann angle.

2.2. Evaluation

The main outcome of this study was intraobserver reliability and interobserver reliability of the measurement of LCHA and BA. We selected BA because its concept is similar to LCHA and BA is the standard assessment for coronal angulation of the elbow.

2.3. Statistical analysis

The mean value and standard deviation of each radiographic parameter was calculated using data from the first and second acquisition sessions of all 6 raters. Intraclass correlation coefficients (ICCs) for measurements of LCHA and BA were calculated according to standard statistical methods. Single measurement was used for intraobserver reliability (2-way mixed model) and interobserver reliability (2-way random model). The ICCs were classified as slight (≤ 0.20), fair (0.21–0.40), moderate (0.41–0.60), substantial (0.61–0.80), or almost perfect agreement (0.81–1.00).^[13] The ICCs for intraobserver reliability and interobserver reliability were calculated with 95% confidence interval (CI) using data from both the first and second acquisition sessions. A prior sample-size calculation based on 6 raters, the width of 95% CI of 0.2, and an ICC of >0.7 , which is generally considered to be significant, indicated that 47 samples were needed.^[14,15] Statistical analyses were performed using SPSS software (version 23.0; SPSS, Chicago, IL).

3. Results

3.1. Patients

Of the 75 patients, a total of 62 patients were included for eligibility and 13 patients were excluded: 7 cases with unavailable radiographs of the uninjured side, 3 cases with unmeasurable radiographs, 2 cases with previous trauma of the elbow, and 1 case with a congenital disorder (van der Hoeve syndrome). There were no patients with flexion contractures of their elbows. There were 45 male patients and 17 female patients with a mean age of 6.6 years (range, 2–11 years) at the time of injury. Radiographs of the right elbow were used in 40 cases (65%).

3.2. Measurement of radiographic parameters

The mean values of each radiographic parameter categorized by age, sex, and laterality are shown in Table 1. The mean LCHA of the 62 patients was 45° (range, 22° to 70°) and the mean BA was 71° (range, 56° to 86°).

Table 1
Radiographic measurements categorized by age, sex, and laterality.

	LCHA, °	BA, °
Total	44.7 ± 8.7	71.1 ± 5.4
Age, y		
2–6 (n=30)	43.9 ± 9.4	72.3 ± 5.2
7–11 (n=32)	45.5 ± 7.9	69.9 ± 5.3
Sex		
Male (n=45)	43.1 ± 8.2	71.2 ± 5.5
Female (n=17)	49.0 ± 8.4	70.7 ± 4.9
Laterality		
Right (n=40)	46.0 ± 9.2	71.1 ± 5.1
Left (n=22)	42.5 ± 7.1	71.0 ± 5.8

The values are given as the mean ± standard deviation.
BA=Baumann angle, LCHA=lateral capitellohumeral angle.

Table 2
Intraobserver reliability and interobserver reliability of the measurement of LCHA and BA.

	LCHA	BA
Intraobserver reliability		
Observer (postgraduate experience of orthopedic surgeons)		
Observer 1 (23 years)	0.89 (0.82–0.93)	0.75 (0.61–0.84)
Observer 2 (13 years)	0.79 (0.68–0.87)	0.75 (0.62–0.84)
Observer 3 (8 years)	0.61 (0.43–0.74)	0.66 (0.49–0.78)
Observer 4 (6 years)	0.57 (0.37–0.71)	0.83 (0.74–0.90)
Observer 5 (3 years)	0.79 (0.68–0.87)	0.72 (0.57–0.82)
Observer 6 (3 years)	0.95 (0.92–0.97)	0.70 (0.55–0.81)
Interobserver reliability		
1st measurement	0.56 (0.46–0.67)	0.52 (0.41–0.63)
2nd measurement	0.51 (0.40–0.62)	0.50 (0.39–0.62)

The values are given as the intraclass correlation coefficients with the 95% confidence interval in parentheses.

BA=Baumann angle, LCHA=lateral humerocapitellar angle.

3.3. Intraobserver reliability and interobserver reliability of the measurement

The ICCs for intraobserver reliability and interobserver reliability for LCHA and BA are shown in Table 2. The ICCs for intraobserver reliability of LCHA measurements were almost perfect for 2 examiners, substantial for 3 examiners, and moderate for 1 examiner with a mean value of 0.77 (range, 0.57–0.95). For BA measurements, the ICCs were almost perfect for 1 examiner and substantial for 5 examiners with a mean value of 0.74 (range, 0.66–0.83).

The ICCs for interobserver reliability between the first and second measurements were both moderate for LCHA (0.56 and 0.51) and for BA (0.52 and 0.50).

4. Discussion

In this study, we performed radiographic measurements and showed the reliability of measurement of LCHA and BA in healthy children. Intraobserver reliability and interobserver reliability of LCHA measurements were about the same as that for BA.

Measurement methods for LCHA and BA have limitations. These angles are defined by the axis of the humeral shaft and a line along the capitellar physis.^[1] Some investigators doubt the reliability of BA because of the difficulty in identifying capitellar growth and distal humeral bony landmarks.^[2,16,17] Other authors have indicated that the metaphyseal border is too irregular in early adolescence, which can alter the measurement of BA.^[18] Shank et al showed that the reliability of LCHA is lower at younger ages because the capitellar physis is immature; its reliability is consistently worse than the reliability of BA.^[5] Despite such problems, reliability of measurement for LCHA and BA are theoretically same in a same patient. Our data demonstrated that the theory that intraobserver reliability and interobserver reliability are about the same between LCHA and BA.

To our knowledge, no earlier studies except Shank's evaluated the reliability of measurement for LCHA.^[5] The intraobserver reliabilities of our data and their data were roughly consistent: 0.77 vs. 0.67 for LCHA and 0.74 vs. 0.86 for BA, while interobserver reliability is not consistent: 0.54 vs. 0.37 for LCHA and 0.51 vs. 0.80 for BA. Other previous studies showed that the ICCs for the BA measurement ranged from 0.77 to 0.98 (intraobserver reliability) and 0.37 to 0.96 (interobserver reliability).^[2,5,7,19] Reliability varies according to the study, with a wide range in the value of ICCs, especially for the interobserver

reliability of BA. The wide range of ICCs can be explained by different research settings in each study.^[15] Though our study settings (62 elbows by 6 testers) are relatively similar to Shank's (71 elbows by 5 testers), the inconsistency might be explained by the different experience of testers. Interobserver reliability is affected by the training or experience of testers. Other studies in similar settings would help to interpret the association of reliability of these parameters.

One limitation of this study is that subjects with supracondylar fracture of the humerus were enrolled retrospectively and radiographs of the uninjured side were used. As a result, the age distribution was not equivalent, 73% of the subjects were male and 65% of the evaluations were for the right elbow. Shank et al enrolled patients with a similar distribution by age, sex, and laterality.^[5] The nonuniform distribution in our study could affect the normal values and reliability of measurement. Therefore, we cannot directly compare the results between the 2 studies given the different conditions. We have only shown that intraobserver reliability and interobserver reliability of LCHA measurements were not inferior to that for BA in the same setting of this study. Another limitation is that the number of radiographs is small to show the normal value categorized by age, sex, and laterality.

In conclusion, LCHA showed almost the same intraobserver reliability and interobserver reliability in measurement as BA, which is the gold standard assessment for coronal alignment of the elbow. We conclude that LCHA showed moderate-to-good reliability in the evaluation of sagittal plane elbow alignment. We consider the results of this study should be helpful to surgeons selecting a sagittal radiographic parameter of the elbow in children.

Acknowledgments

The authors thank to K. Otsuka, Dr. K. Hayakawa, and other members of the Department of Orthopedic Surgery, Fujita Health University for their technical support. The authors are also grateful to Prof. M. Matsumoto, Prof. M. Nakamura, Dr. K. Sato, Dr. T. Iwamoto, and other members in the Hand Surgery group of Keio University School of Medicine for their helpful discussion.

Author contributions

Conceptualization: Taku Suzuki, Takashi Tsuji, Katsuji Suzuki, Harumoto Yamada.

Data curation: Masaki Hasegawa.

Formal analysis: Taku Suzuki.

Methodology: Masaki Hasegawa, Taku Suzuki, Takashi Kuroiwa, Yusuke Oka, Atsushi Maeda, Hiroki Takeda, Kanae Shizu.

Project administration: Harumoto Yamada.

Software: Masaki Hasegawa, Taku Suzuki.

Supervision: Harumoto Yamada.

Writing – original draft: Masaki Hasegawa, Taku Suzuki.

Writing – review & editing: Taku Suzuki, Takashi Tsuji, Katsuji Suzuki, Harumoto Yamada.

References

- [1] Beaty JH, Kasser JR, Flynn JM, Skaggs DL, Waters PM. Evaluation of pediatric distal humeral fractures. *Rockwood & Wilkins' Fractures in Children* 8th ed Lippincott Williams & Wilkins, Philadelphia, PA:2015;565–79.
- [2] Goldfarb CA, Patterson JM, Sutter M, et al. Elbow radiographic anatomy: measurement techniques and normative data. *J Shoulder Elbow Surg* 2012;21:1236–46.
- [3] Hasegawa M, Suzuki T, Kuroiwa T, et al. Reliability and validity of radiographic measurement of humerus-elbow-wrist angle in healthy children. *JBJS OA* 2017;2:e0012.
- [4] Zampagni ML, Casino D, Zaffagnini S, et al. Estimating the elbow carrying angle with an electrogoniometer: acquisition of data and reliability of measurements. *Orthopedics* 2008;31:370.
- [5] Shank CF, Wiater BP, Pace JL, et al. The lateral capitellohumeral angle in normal children: mean, variation, and reliability in comparison to Baumann's angle. *J Pediatr Orthop* 2011;31:266–71.
- [6] Chapleau J, Canet F, Petit Y, et al. Validity of goniometric elbow measurements: comparative study with a radiographic method. *Clin Orthop Relat Res* 2011;469:3134–40.
- [7] Moraleda L, Valencia M, Barco R, et al. Natural history of unreduced Gartland type-II supracondylar fractures of the humerus in children: a two to thirteen-year follow-up study. *J Bone Joint Surg Am* 2013;95:28–34.
- [8] Herman MJ, Boardman MJ, Hoover JR, et al. Relationship of the anterior humeral line to the capitellar ossific nucleus: variability with age. *J Bone Joint Surg Am* 2009;91:2188–93.
- [9] Simanovsky N, Lamdan R, Hiller N, et al. The measurements and standardization of humerocondylar angle in children. *J Pediatr Orthop* 2008;28:463–5.
- [10] Ariyawatkul T, Eamsobhana P, Kaewpornawan K. The necessity of fixation in Gartland type 2 supracondylar fracture of the distal humerus in children (modified Gartland type 2A and 2B). *J Pediatr Orthop B* 2016;25:159–64.
- [11] Pace JL, Wiater B, Schmale G, et al. Baumann angle and radial-ulnar overlap: a radiographic study to control for the angle of the X-ray beam. *J Pediatr Orthop* 2012;32:467–72.
- [12] Tuomilehto N, Kivisaari R, Sommarhem A, et al. Outcome after pin fixation of supracondylar humerus fractures in children: postoperative radiographic examinations are unnecessary. *Acta Orthop* 2017;88:109–15.
- [13] Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics* 1977;33:159–74.
- [14] Giraudeau B, Mary JY. Planning a reproducibility study: how many subjects and how many replicates per subject for an expected width of the 95 per cent confidence interval of the intraclass correlation coefficient. *Stat Med* 2001;20:3205–14.
- [15] Karanicolas PJ, Bhandari M, Kreder H, et al. Evaluating agreement: conducting a reliability study. *J Bone Joint Surg Am* 2009;91(suppl 3):99–106.
- [16] Nacht JL, Ecker ML, Chung SM, et al. Supracondylar fractures of the humerus in children treated by closed reduction and percutaneous pinning. *Clin Orthop Relat Res* 1983;177:203–9.
- [17] Camp J, Ishizue K, Gomez M, et al. Alteration of Baumann's angle by humeral position: implications for treatment of supracondylar humerus fractures. *J Pediatr Orthop* 1993;13:521–5.
- [18] Keenan WN, Clegg J. Variation of Baumann's angle with age, sex, and side: implications for its use in radiological monitoring of supracondylar fracture of the humerus in children. *J Pediatr Orthop* 1996;16:97–8.
- [19] Dai L. Radiographic evaluation of Baumann angle in Chinese children and its clinical relevance. *J Pediatr Orthop B* 1999;8:197–9.