Pediatric elbow measurement parameters: Evaluation of the six angles in inter- and intra-observer reliability

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ABSTRACT

Background: Several radiographic measurements of the humerus can be used to evaluate the treatment outcome of supracondylar fractures in children. Because of the cartilaginous nature of the immature elbow, interpretation of radiographs around this area is sometimes challenging and can be unreliable. This study was conducted to determine the inter-observer and intra-observer reliability of the six commonly used radiographic measurements of the distal humerus.

Method: The Baumann angle, humero-ulna angle, metaphyseal-diaphyseal angle, radial epiphyseal angle, shaft-condylar angle and lateral capitellohumeral angle of the humerus were measured by two observers on the radiographs of uninjured elbows from 58 children. The values between each measurement were compared and correlated using a Pearson coefficient of correlation to determine the inter-observer and intra-observer reliability.

Results: All of the radiographic parameters showed excellent intra-observer reliability with the correlation coefficient values of the Baumann angle, humero-ulna angle, metaphyseal-diaphyseal angle, radial epiphyseal angle, shaft-condylar angle, lateral capitellohumeral angle as 0.945, 0.95, 0.909, 0.888, 0.961 and 0.975 ($p < 0.001$), respectively. The inter-observer reliability of the Baumann and humero-ulna angles were also found to be highly correlated at $r = 0.843$ ($p < 0.001$) and 0.878 ($p < 0.001$), respectively. The metaphyseal-diaphyseal angle had poor reliability with $r = 0.136$ ($p = 0.291$) while the radial epiphyseal angle, shaft-condylar angle, and lateral capitellohumeral angle demonstrated good reliability with $r = 0.675$ ($p < 0.001$), 0.747 ($p < 0.001$), and 0.686 ($p < 0.001$), respectively.

Conclusion: The Baumann angle and humero-ulna angle measurements of distal humerus showed excellent inter- and intra-observer reliability. Both parameters represent repeatable and reliable methods for determining the outcome of supracondylar humeral fractures in pediatric population.

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1. Introduction

A supracondylar humeral fracture is one of the most common elbow injuries in children.^{1–3,12} The malunion of this fracture can lead to lifelong deformity such as cubitus varus or valgus due to the limited remodeling potential in this area. Clinical and radiographic

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determinations of the quality of reduction in supracondylar fractures have a major role in avoiding this complication.^{1,2,4–7} The radiographic measurements commonly used for this purpose include: the Baumann angle, humero-ulna angle (HUA), shaft-condylar angle (SCA), metaphyseal-diaphyseal angle (MDA), radial epiphyseal angle (REA), and lateral capitellohumeral angle (LCHA). The goal of supracondylar fracture reduction is to achieve the normal range of these angles in order to prevent malunion. Therefore, the reliability of the measurement of these angles is very important and should be consistent among different levels of orthopaedic surgeons.

After literature review, we found a few studies that reported a normal value and reliability of these angles. A study of the non-traumatic humerus in 114 children, ages 2–13 years, found the

average Baumann angle to be 72° (SD = 4, 95% CI $64\text{--}81^\circ$). The angle remained constant throughout this age range and was not different between genders.¹ Other studies further investigated the variability in the measurement of BA and demonstrated that both the inter- and intra-observer reliability were excellent.^{2,3,8} A study by Barcellos et al. indicated that radiographic HUA was a good representation of the clinically measureable carrying angle of the elbow. They found that the angle progressively increased with age and varied between genders. The average carrying angle was $12.78 \pm 5.35^\circ$ for girls and $11.20 \pm 4.45^\circ$ for boys.⁴ MDA is another parameter widely used as a guide to treat supracondylar fractures of the humerus in children⁵; however, information regarding the reliability of this measurement is sparse. REA can be used to evaluate a supracondylar fracture of the humerus until patients reach maturity. A normal value of this measurement is quite constant at 90° and has shown excellent reliability compared with the Baumann angle and the HUA.⁵

The SCA and LCHA are measured on the lateral view of the elbow to evaluate flexion/extension deformity. Literature showed the normal value of SCA as 40° , while reports on inter-observer reliability and intra-observer reliability of this angle are still limited. For the LCHA, Shank, et al. found the average value to be $51 \pm 6^\circ$ on uninjured humeri, and the angle did not change significantly by age and gender. They also showed that the LCHA had good intra-observer reliability but fair inter-observer reliability.⁸ To our knowledge, there was limited information about the reliability of these aforementioned radiographic parameters. The purpose of this study was to determine the inter-observer and intra-observer reliability of these six radiographic parameters of the pediatric humerus.

2. Material and method

After IRB approval, retrospective data collection was performed on pediatric elbow radiographs. The hospital database was searched for children below 14 years of age with fracture around the elbow. We only included the radiographs of contralateral uninjured elbows that had adequate x-ray quality for measurement. The exclusion criteria were previous fractures and/or surgeries of the elbow, or other bone diseases and conditions that may disturb growth of the elbow (e.g., infection, tumor, metabolic bone disease, achondroplasia, etc.). The sample size was calculated using the single mean value from the previous study of the LCHA by Shank et al.,⁸ and indicated that 25 is an adequate number for study subjects. Fifty-eight patients had radiographs that matched the study criteria. All radiographs were taken digitally by an experienced technician, following standard techniques. All observers received specific instructions on how to measure the angles in order to ensure a standardized technique. All radiographs were presented to the observers in a random fashion, blinding any identifying patient information.

The first 4 angles (Fig. 1A–D) were measured using plain anteroposterior (AP) radiographs of the elbow. For the Baumann angle (Fig. 1A), the first line was the longitudinal axis of the humerus. The second line was drawn through the physis of the lateral condyle immediately at the edge of metaphysis. The Baumann angle was the proximal lateral corner of the intersection between these two lines.¹ The HUA (Fig. 1B) was the angle between the long axis of the humerus and the long axis of the ulnar. A positive value indicates a valgus carrying angle observed clinically.⁴ The MDA (Fig. 1C) was measured by drawing the first line along the axis of humeral shaft. The second line was drawn passed the widest part of the metaphysis. The MDA is the proximal lateral angle between these two lines.⁵ The REA (Fig. 1D) was also determined by drawing the first line along the axis of the humerus. The second line was drawn

passed the epiphysis of the radial head. The REA was defined as the proximal lateral corner of these two lines.⁷

The SCA and LCHA (Fig. 1E–F) were measured on the lateral plain x-ray images of the elbow. For the SCA (Fig. 1E), the first line is the anatomical axis of the humerus. The second line bisects the anteroposterior axis of lateral condyle. The SCA was the anterior distal corner of these two lines.⁹ The LCHA (Fig. 1F) was measured by drawing the first line along the anterior cortex of humerus. The second line was drawn along the proximal border of the capitellar ossification center. The LCHA was the anterior proximal corner of these two lines.⁸

These radiographic parameters were measured by 2 pediatric orthopedic fellows. Both observers repeated their measurements on all 58 radiographs in a similar fashion (a total of 232 observations for each parameter) after a period of at least two weeks from the initial assessment to avoid recall bias. Both observers were blind to the results of their first evaluation. The study design was categorized as a cross-sectional, descriptive study. The value of each parameter was reported as a mean and standard deviation (SD). In order to determine the inter-observer (IEOR) and intra-observer reliability (IAOR), because the measurements were on a numerical scale, a Pearson coefficient of correlation was used. The correlation value (*r*) of 0–0.25 indicated poor reliability. Those from 0.25 to 0.50 indicated a fair degree of reliability. Those from 0.5 to 0.75 indicated good reliability, and those greater than 0.75 indicated excellent reliability. SPSS Version 18.0 (SPSS, Inc., Chicago, IL, USA) was used for data analysis.

3. Results

Thirty-five male (60.3%) and 23 female (39.7%) were included in this study. Thirty-one images (53.4%) were from the left elbow and 27 (46.6%) were from the right elbow. The mean age of the patients was 5.52 (with a range from 1 to 13) years old. The measurements by both observers were significantly different for the Baumann angle, MDA and LCHA ($p = 0.036$, $p < 0.001$ and $p = 0.043$, respectively) by used pair T test (Table 1). Excellent intra-observer reliability was found in all six radiographic parameters. The correlation coefficient values for the Baumann angle, HUA, MDA, REA, SCA and LCHA were 0.945, 0.95, 0.909, 0.888, 0.961 and 0.975 ($p < 0.001$), respectively. An excellent inter-observer reliability was found for the measurement of the Baumann angle and HUA ($r = 0.843$ and 0.878 , respectively; $p < 0.001$). The MDA had poor reliability with $r = 0.136$ ($p = 0.291$). The REA, SCA and LCHA showed good inter-observer reliability with the correlation coefficient values of 0.675 ($p < 0.001$), 0.747 ($p < 0.001$) and 0.686 ($p < 0.001$), respectively (Table 2 and Fig. 2).

4. Discussion

Supracondylar fractures are one of the most common pediatric elbow fractures. Complications from malunions of this fracture can lead to permanent deformity due to the limited remodeling potential of this area. Post-operative measurements that indicate that proper reduction is crucial in preventing complications from malunion.^{11,12} The Baumann angle, HUA, MDA, REA, SCA and LCHA are parameters commonly used to evaluate elbow injuries.^{5,9–14} To our knowledge, there has been limited information regarding the reliability of these radiographic measurements. The mean normal value for the Baumann angle, HUA, MDA, REA, SCA and LCHA found in this study showed no difference when compared with previous studies.^{1,4,5,7,8} The result of this study demonstrated excellent inter-observer and intra-observer reliability in Baumann angle and HUA. This finding regarding Baumann angle corresponds with previous studies from Mauricio et al.² and Craig et al.⁸ The LCHA in this study

Fig. 1. A: Baumann angle, 1 B: humero-ulnar angle (HUA), 1C: Metaphyseal-diaphyseal angle (MDA), 1D: radial epiphyseal angle (REA), 1 E: shaft condylar angle (SCA), 1 F: lateral capitellohumeral angle (LCHA).

Table 1

Parameters measured by each pediatric orthopedic fellow.

Parameters	1 st fellow measurement (Mean $\pm$ SD)	2 nd fellow measurement (Mean $\pm$ SD)	P value
Baumann	70.69 $\pm$ 6.684	73.35 $\pm$ 6.80	0.036
HUA	6.31 $\pm$ 5.289	5.89 $\pm$ 4.75	0.654
MDA	88.50 $\pm$ 3.404	91.03 $\pm$ 3.96	<0.001
REA	91.12 $\pm$ 6.77	90.60 $\pm$ 6.03	0.663
SCA	40.10 $\pm$ 6.24	39.10 $\pm$ 6.254	0.391
LCHA	51.81 $\pm$ 7.56	48.87 $\pm$ 7.879	0.043

Table 2

Intra and inter-observer reliability of six radiographic parameters.

Parameters	Intra-observer (r)	95% CI	P value	Inter-observer (r)	95% CI	P value
Baumann	0.945	0.907–0.967	<0.001	0.843	0.735–0.907	<0.001
HUA	0.950	0.916–0.971	<0.001	0.878	0.794–0.928	<0.001
MDA	0.909	0.846–0.946	<0.001	0.136	–0.46–0.489	0.291
REA	0.888	0.811–0.934	<0.001	0.675	0.451–0.808	<0.001
SCA	0.961	0.933–0.977	<0.001	0.747	0.572–0.850	<0.001
LCHA	0.975	0.958–0.985	<0.001	0.686	0.47–0.814	<0.001

showed correlation value of 0.686 which indicated good reliability while the previous study⁸ found this parameter to have fair inter-observer reliability.

The ideal radiographic measurement should be simple and repeatable, so it can be applied by a wide range of healthcare practitioners regardless of their level of expertise. Therefore, the Baumann angle and HUA, which consistently demonstrated excellent reliability across all studies, including ours, should be confidently used as a regular basis to determine the outcome of a pediatric supracondylar humeral fracture.

The limitation of the study was that the measurement should

include surgeon with different working experience such as orthopedics resident, paediatric orthopaedic surgeon.

5. Conclusion

The Baumann angle and humero-ulna angle of the humerus showed excellent inter- and intra-observer reliability. Both parameters represent simple, repeatable, and reliable measurements that can be used to determine the outcome of supracondylar humeral fractures in the pediatric population.

Fig. 2. Inter and intra observer reliability of six radiographic parameters.

Fig. 2. (continued).

Conflict of interest declaration

The authors hereby declare no personal or professional conflicts of interest regarding any aspect of this study.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.jcot.2018.07.019>.

References

- Williamson DM, Coates CJ, Miller RK, Cole WG. Normal characteristics of the Baumann (humero capitellar) angle: an aid in assessment of supracondylar fractures. *J Pediatr Orthop*. 1992 Sep-Oct;12(5):636–639.
- Silva M, Pandarinath R, Farnig E, et al. Inter- and intra-observer reliability of the Baumann angle of the humerus in children with supracondylar humeral fractures. *Int Orthop*. 2010 Apr;34(4):553–557.
- Camp J, Ishizue K, Gomez M, Gelberman R, Akeson W. Alteration of Baumann's angle by humeral position: implications for treatment of supracondylar humerus fractures. *J Pediatr Orthop*. 1993 Jul-Aug;13(4):521–525.
- Simanovsky N, Lamsan R, Hiller N, Simanovsky N. The measurement and standardization of humerocondylar angle in children. *J Pediatr Orthop*. 2008 Jun;28(4):463–465.

- Beatty JH, Kasser JR. The elbow region: general concepts in the pediatric patient. In: Beatty JH, Kasser JR, eds. *Rockwood and Wilkins Fractures in Children*. seventh ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2010:563–576.
- Skaggs DL, Hale JM, Basett J, Kaminsky C, Kay RM, Tolo VT. Operative treatment of supracondylar fractures of the humerus in children. The consequences of pin placement. *J Bone Joint Surg Am*. 2001 May;83-A(5):735–740.
- Otsuka NY, Kasser JR. Supracondylar fractures of the humerus in children. *J Am Acad Orthop Surg*. 1997 Jan;5(1):19–26.
- Shank CF1, 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 Apr-May;31(3):266–271.
- Mulpruek P, Angsanuntsukh C, Woratanarat P, Sa-Ngasoongsong P, Tawonsawatruk T, Chanplakorn P. Shaft-Condylar Angle for surgical correction in neglected and displaced lateral humeral condyle fracture in children. *Acta Orthop Belg*. 2015 Sep;81(3):384–391.
- Omid R, Choi PD, Skaggs DL. Supracondylar humeral fractures in children. *J Bone Joint Surg Am*. 2008 May;90(5):1121–1132.
- Acton JD, McNally MA. Baumann's confusing legacy. *Injury*. 2001 Jan;32(1):41–43.
- Kaewpornnawon K. Comparison between closed reduction with percutaneous pinning and open reduction with pinning in children with closed totally displaced supracondylar humeral fractures: a randomized controlled trial. *J Pediatr Orthop B*. 2001 Apr;10(2):131–137.
- 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 Jan-Feb;16(1):97–98.
- Pirone AM, Graham HK, Krajchich JL. Management of displaced extension-type supracondylar fractures of the humerus in children. *J Bone Joint Surg Am*. 1988 Jun;70(5):641–650.