Review Article

The normal values and the relationship between baumann's angle and the trochleocapitellar index in pediatric elbows

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Abstract: The study assessed the normal values and the relationship between Baumann's angle and the trochleocapitellar index. Normal anteroposterior elbow radiographs of children were examined. The mean values and reference intervals of baumann's angle and the trochleocapitellar index were determined as well as their variability with sex, age, and race. The relationship between Baumann's angle and the trochleocapitellar index was examined using Pearson's product moment correlation. A mean value of Baumann's angle of 72.4^{o} was determined with a reference interval of 64° to 80°. The mean trochleocapitellar index was found to be 0.48 with a reference interval of 0.25 to 0.85. Baumann's angle and the trochleocapitellar index did not vary with age or sex. The trochleocapitellar index was found to positively correlate with Baumann's angle. The correlation coefficient and the coefficient of determination values for the linear relationship between the two measurements were 0.589 and 0.347 respectively. We concluded that baumann's angle and the trochleocapitellar index do not vary with age, sex, or race. There is a positive correlation between Baumann's angle and the trochleocapitellar index. Further studies on the role of the trochleocapitellar index in the assessment of the final carrying angle of pediatric elbows need to be conducted.
Keywords: Humeral supracondylar fracture; Trochleocapitellar angle, Baumann's angle, carrying angle.

INTRODUCTION

Baumann's angle is an important radiographic tool used in the assessment of the quality of reduction of humeral supracondylar fractures in children. It plays a vital role in the prevention of varus malunion in these fractures through providing a good estimate of the carrying angle of the elbow (Worlock P. 1986). It can be used both intraoperatively to assess the quality of reduction of these fractures and in the postoperative follow-up period to assess for loss of reduction after surgery. The reference interval for the angle ranges between of 64° and 81° with a mean value of 72°. Values of the angle do not vary with age or sex (Williamson, D. M. *et al.,* 1992).

Despite its wide use, Baumann's angle has some limitations. It can only measure fracture displacement in the coronal plane despite the fact that these fractures may also exhibit sagittal plane and rotational displacement (Gorelick, L. *et al.,* 2014). This

calls for a need for an alternative radiographic tool that could address the limitations of the angle.

The Trochleocapitellar Index (TCI) was described by Gorelick *et al.,* (2014) as a potential alternative to Baumann's angle (Gorelick, L. *et al.,* 2014). It is an index calculated from the ratio between two angles, the trochlear and the capitellar. Both of these angles are potentially disrupted in humeral supracondylar fractures. Research on the index is still at its early stages. This study attempts to describe the normal values of the index and to study its relationship with Baumann's angle.

Experimental Section

All procedures performed in the study were in accordance with the ethical standards of the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Enrollment into the study was subject to the participant's guardian informed consent. Children less than 12 years of age were

recruited. Only children with true anteroposterior radiographs based on the criteria described by Grayson were included (Grayson D. E. 2005). Radiographs that were of poor quality, obviously oblique, and those in which the trochlear and capitellar angles were difficult to determine were excluded from the study. Children with previous elbow fractures and congenital upper extremity anomalies were also excluded because their normal elbow anatomy is likely to be disrupted.

A consecutive sampling technique was used to recruit study participants. Data was collected in two different arms. The first arm included patients admitted to the Orthopaedics and Trauma department. In this group of patients, radiographs of their normal uninjured elbows were taken after consent was obtained. The second arm of the data collection process took place at the department of diagnostic radiology. Normal anteroposterior radiographs of eligible children that were taken for suspected elbow fractures in the period between 2010 and 2015 were included in the study. In this group, fractures were ruled out through the initial radiologist's report and a second verification by the investigator during retrieval of the radiographs.

The humeral, capitellar, and the trochlear or alternative trochlear lines were digitally drawn on the x-rays. The Baumann's, trochlear, and capitellar angles were measured digitally using Image J ® software and the trochleaocapitellar index (TCI) was calculated for each radiograph based on the method used by Gorelick *et al.,* (2014). Figure 1 demonstrates the technique used for the determination of the TCI and Baumann's angle.
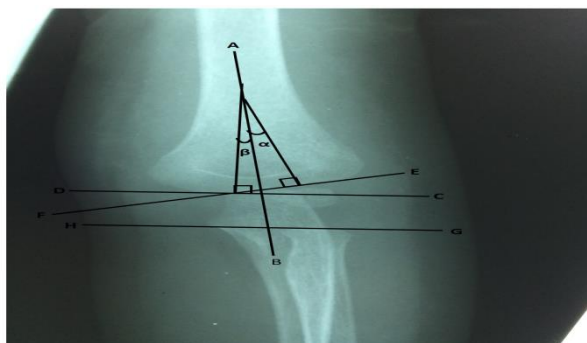

Figure 1: A radiograph showing the technique used for determining the TCI. AB humeral line, CDtrochlear line, EF capitellar line, GH alternative trochlear line, α capitellar angle, β trochlear angle

Data was analyzed using Statistical Package for Social Sciences SPSS® software version 21. Proportions and means were used to summarize the different variables. Paired t-test was used to compare the mean Baumann's angle and the TCI across age groups and patients sexes. The correlation between Baumann's angle and the TCI was assessed using Pearson's Correlation. A p value of less than 0.05 was considered for statistical significance.

RESULTS AND DISCUSSION
Results

The study enrolled 45 children. 28.9% of them were below 6 years of age and 33.3% were females. The mean Baumann's angle in the study group was 72.4^o with a reference interval of 64° to 80°. Patients less than 6 years of age had a mean angle of 72° while patients aged 6 years or more had a mean angle value of 72.5^o. The mean Baumann's angle values in male and female patients were 72.2^o and 72.6^o respectively. The variation in the values of Baumann's angle across age groups and sex was not statistically significant.

The mean TCI value was 0.48 with a reference interval of 0.25 to 0.85. Patients aged less than 6 years had a mean TCI value of 0.46 while those aged 6 years or more had a mean TCI of 0.49. The mean TCI values for male and female patients were 0.49 and 0.47 respectively. There was no statistically significant difference in the mean TCI based on age or sex.

The relationship between Baumann's angle and the TCI was assessed using Pearson's Correlation. There was a statistically significant positive correlation between the two variables with a Pearson's Correlation Coefficient (r) value of 0.589 (p<0.001). The coefficient of determination (r^2) for the linear relationship between Baumann's angle and the TCI was 0.347. The linear relationship between the TCI and Baumann's angle is shown in a scatterplot in figure 2.
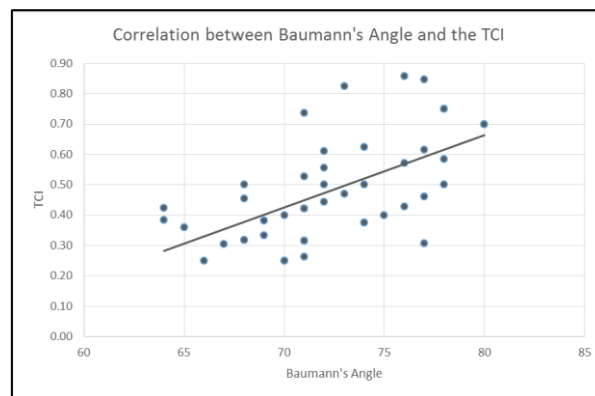

Figure 2: A Scatterplot demonstrating the relationship between Baumann's angle and the trochleocapitellar index

DISCUSSION

Prevention of the complications associated with pediatric humeral supracondylar fractures is an important management aspect of these injuries. Varus malunion, the commonest of these complications could be effectively prevented through ensuring adequate reduction of these fractures by restoration of the normal Baumann's angle of the elbow. The angle however has some limitations. Its values can vary among individuals as well as with whether the x-ray examined is a true anteroposterior view of the elbow (Camp, J. *et al.,*

1993). The TCI was proposed as a potential alternative to Baumann's angle. This study attempted to define the normal values of both Baumann's angle and the TCI and to examine the relationship between these two parameters in our setting.

The study found that the value of Baumann's angle does not vary with race, age, or sex. The mean value and the reference interval for the angle from this study are comparable to those in studies done on Caucasian, Asian, and African children. Williamson *et al.,* evaluated the normal values of Baumann's angle and its variation with age and sex on 114 Australian children. They reported a mean value of 72 ^{o} with a reference interval of 64° to 81°. The values of the angle in their study did not vary with age or sex (Williamson, D. M. *et al.,* 1992). In Asia, Ko *et al.,* conducted a baseline normative study to determine the values of the angle in Chinese children. The study determined a mean value of 70° for the angle that does not vary with age or sex. In African children, a study by Balogun *et al.,* assessed the normal values of Baumann's angle in Nigerian children. They reported a mean angle value of 71.78 ^{o}.

This study provided only the second independent scientific enquiry on the normal values of the TCI. Gorelick *et al.,* in Israel published the first paper that described the index (Gorelick, L. *et al.,* 2014). They described a mean TCI value of 0.4 and a reference interval of 0.25 to 0.8. These values did not significantly vary from those described in this study. This similarity in the TCI values in the two studies was expected. The capitellar angle that is used in determination of the TCI is, in essence, a variation of Baumann's angle (Acton, J. D., & McNally, M. A. 2001). Since Baumann's angle value does not vary with race, we also expect the same for the TCI since it is at least partially influenced by the values of the angle.

This study provides the first enquiry into how the TCI relates to Baumann's angle in normal pediatric elbows. The findings concluded a statistically significant, moderately positive correlation between the two measurements. A coefficient of determination value of 0.347 for the linear relationship between Baumann's angle and the TCI tells us that 34.7% of the variability in the values of the TCI could be explained by the changes in the values of Baumann's angle. Baumann's angle is known to be an important tool to determine the carrying angle of the elbow. Worlock *et al.,* stated that the angle inversely correlates with the carrying angle of the elbow (Worlock P. 1986). Based on the positive correlation between Baumann's angle and the TCI, we can safely conclude that the TCI is also inversely correlated with the carrying angle of the elbow.

CONCLUSION

The study supports the assertion that Baumann's angle does not vary with race, age, and sex (Williamson, D. M. *et al.,* 1992). Because the TCI is influenced by the values of Baumann's angle, and based on the findings of the study, we can also conclude that TCI values do not vary with age, sex, or race. The TCI may have a potential role in assessing the carrying angle of the elbow in children. Further studies with larger sample sizes and appropriate sampling techniques are however required to confirm this finding.

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