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# Predictors for losing reduction after reposition in conservatively treated both-bone forearm fractures in 38 children

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ABSTRACT

*Backgrounds:* Alignment loss after reduction and cast immobilisation of angulated and/or complete displaced forearm fractures is challenging. Many authors have tried to describe risk factors and create indices (initial angulation, initial complete displacement, lack of anatomic reduction, cast and padding index) in order to identify those fractures that are prone to losing their alignment during treatment.
*Methods:* This retrospective case-control study included children sustaining both-bone forearm fractures treated by closed reduction and cast immobilisation. Basic characteristics were recorded and radiographs evaluated to measure displacement and angulation before and after reduction, cast index and padding index. The primary outcome was loss of reduction during the immobilisation period.
*Results:* Group A consisted of 22 patients in whom >5° reduction loss was seen during cast immobilisation. Group B consisted of 16 patients with <5° reduction loss. After multivariate analyses we found group A included more broken cortices, with a statistically significant higher number of initial displaced fractures ($p < 0.001$ and $p = 0.010$) and residual displacement ($p = 0.022$). The cast and padding index did not differ significantly between groups ($p = 0.77$ and 0.15 respectively).
*Conclusions:* Cast and padding index did not correlate well as predictor of alignment loss, although in this study cortical stability seemed more important towards predicting alignment loss.


## 1. Introduction

A paediatric both-bone forearm fracture (BBFF) with angular deformity is a common injury that necessitates treatment, although the optimal regime is still a topic of debate.[1–8] Forearm fractures account for 30–45% of all paediatric fractures;[9–12] 75–84% are located in the distal third of the forearm, 13–18% include the middle third and 1–7% the proximal part of the radius and ulna.[11,13–15] Angular deformation and complete fracture displacement are common complicating factors. They frequently require closed reduction or even operative management to correct the deformity and add stability to prevent malunion. This can pre-empt consequences for range of motion, function and cosmesis.

A frequent complication after closed reduction and cast immobilisation of paediatric forearm fractures is loss of reduction. This is estimated to occur in one third of repositions, though incidences vary in the literature (7%–91%).[1,16–21]

Many authors have tried to determine risk factors and create indices in order to identify unstable fractures and unfavourable immobilisation characteristics, which are considered to have a tendency to redisplace.[18,22–25] Risk factors mentioned in literature include initial complete displacement of >50% (of the radial width) and inaccuracy of the reduction.[17,19,21] The quality and extent of the cast are a topic of dispute, with multiple indices proposed for indicating its adequacy.[18,22–25]

Little is known of the effect of implementing these risk factors to prevent loss of reduction, which has not led to widespread use in common day practice.(26) This is why in this study 38 reduced both-bone forearm fractures (BBFFs) were retrospectively analysed to implement risk factors for losing alignment.

This study further determines and confirms predictors of reduction loss after acceptable reduction and cast immobilisation as treatment for angular deformed and displaced paediatric BBFFs.

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## 2. Methods

### 2.1. Participants

We searched in the archives of both affiliations from 2004-2008 and 2002–2012 for patients younger than age 16 who had sustained a BBFF (Table 1). A total of 282 patients were found, 35 of whom met the inclusion criteria (younger than age 16, both-bone forearm fracture, treated by closed reduction, cast immobilisation and loss of acceptable reduction). Patients sustaining an epiphyseal, torus, open, pathological, or Galeazzi or Monteggia fracture were excluded. Fractures older than one week, previous fractures in the ipsilateral arm, lack of or insufficient quality of the radiographs and performed osteosynthesis due to unacceptable reduction were also excluded from our study. After exclusion 22 patients remained for evaluation. Three patients were excluded because in retrospect no reduction was performed, eight patients due to missing (or non-existing) radiographs, one patient owing to the fact that the fracture was a re-fracture, and one patient was excluded due to performed osteosynthesis.

A matched control group (based on initial displacement criteria and second patient demographics) of 16 patients was used with the same inclusion and exclusion criteria, except for loss of reduction. Loss of reduction was defined as >5° of reangulation or >50% increase of fracture displacement. Acceptable reduction was defined as <15° of angulation and/or <50% fracture displacement, independently of the direction.

### 2.2. Measurements

Basic characteristics were recorded. Radiographs were taken of trauma at 1 day, 1 week, 2 weeks, 4 weeks, 8 weeks and 1 year after reduction and were reviewed for hospitals protocols. Two independent observers measured cast index, padding index, angular deformity of the radius, severity of the fracture, percentage of displacement and shortening. Angular deformity was defined in degrees and fracture displacement as a percentage of the total radial or ulnar width. The cast index and padding index were defined according to Bhatia and Housden[18] (Fig. 1a–d).

Both observers measured indices of the cast after reduction and mean values were calculated. Fracture severity classification was 1 fractured cortex, 2 fractured cortices (with or without fracture displacement) and complete fracture displacement, with or without shortening (Fig. 2). Severity was measured in both radius and ulna.

Angular deformity of the radius was measured at the mentioned moments. Two groups were identified: group A consisted of patients in whom more than 5° loss of reduction was seen after reduction and cast immobilisation, group B consisted of patients with less than 5° loss of reduction.

### 2.3. Treatment

Reduction was performed in all patients under general anaesthesia when angulation exceeded >15° of angulation and/or >50% of fracture displacement.[6,8,10,27–29] All patients were subsequently treated with an above-elbow cast in a neutral position for 10–14 days, followed by a circular above-elbow cast in proximal and middle third fractures or a below-elbow cast in distal fractures. Length of cast treatment varied between 4 and 6 weeks.

### 2.4. Statistics

The matched control group was calculated to consist of 15 patients based on displacement criteria. Distributions of the continuous data were tested for normality using the Shapiro-Wilk Normality Test. Groups were compared using the Independent Samples Mann-Whitney *U* Test for continuous data and the Fisher Exact Test or Chi-Square Test for categorical data. A p-value of 0.05 was considered statistically significant.

Multivariable logistic regression analysis was performed after univariate analysis. Variables reaching significance at a level of $p < 0.10$ were considered statistically significant. For interobserver reliability a Bland-Altman analysis was used. Statistical analysis was performed using SPSS 20.0 (SPSS Inc., Chicago).

## 3. Results

A total of 38 patients were analysed; 74% were male and the mean age of the total population was 7.5 years. The majority of the fractures ($n = 26$, 68%) were located in the distal third; only one proximal third fracture was found (Table 1). The most common direction of angulation was dorsal ($n = 34$, 89%) and no volar angulation was seen in the group with loss of reduction ($p = 0.025$). Either radial or ulnar deviation was observed in 25 patients (76%). In retrospect, the criteria used for reduction were ≥15° of angulation and/or >70% of displacement of the radial fracture. After reduction a mean residual angulation of 5.3° and a mean residual fracture displacement of 10% was seen.

Group A consisted of 22 patients in whom ≥5° loss of reduction was seen after reduction and cast immobilisation. Group B consisted of 16 patients with no loss or <5° loss of reduction. Basic characteristics did not differ between the groups. Angular deformity at trauma was not significantly different between the groups (23° vs 26°, $p = 0.18$). The severity of the fracture (Fig. 2) of both radius ($p < 0.001$) and ulna ($p = 0.010$) was different between the groups. Loss of alignment occurred significantly more frequently in patients with complete displacement of the fractured bones. Complete fracture displacement of the radius showed an odds ratio of 22.8 compared to 1 cortex in univariate exact logistic regression analysis, while 2 fractured cortices did not give a higher likelihood than 1 fractured cortex. Mean fracture displacement of the radius in the loss of reduction group was found to be 62% (SD 46) of the radial width. In the group without loss of reduction this percentage was only 4% (SD 12) (Tables 2 and 3). When comparing any fracture displacement of the radius (>0%) to no displacement at all (0%), an odds ratio of 7.9 was seen. The group with fracture displacement therefore had a higher likelihood of losing reduction. Although not significant, every 10% increase in displacement of the radial fracture gave a 50% higher chance of losing reduction.

**Table 1**
Patient demographics.

| median/n (SD/%) | Total (n = 38) | Group A loss of reduction (n = 22) | Group B no loss of reduction (n = 16) | p-value |
|---|---|---|---|---|
| Age | 7.47 yrs (SD 2.33) | 6.81 yrs (SD 1.6) | 7.95 yrs (SD 2.68) | 0.14 |
| Gender (n,%) | | | | |
| Male | 28 (74%) | 16 (73%) | 12 (75%) | 1.00 |
| Female | 10 (26%) | 8 (27%) | 4 (25%) | |
| Side, right | 21 (55%) | 12 (55%) | 9 (56%) | 1.00 |

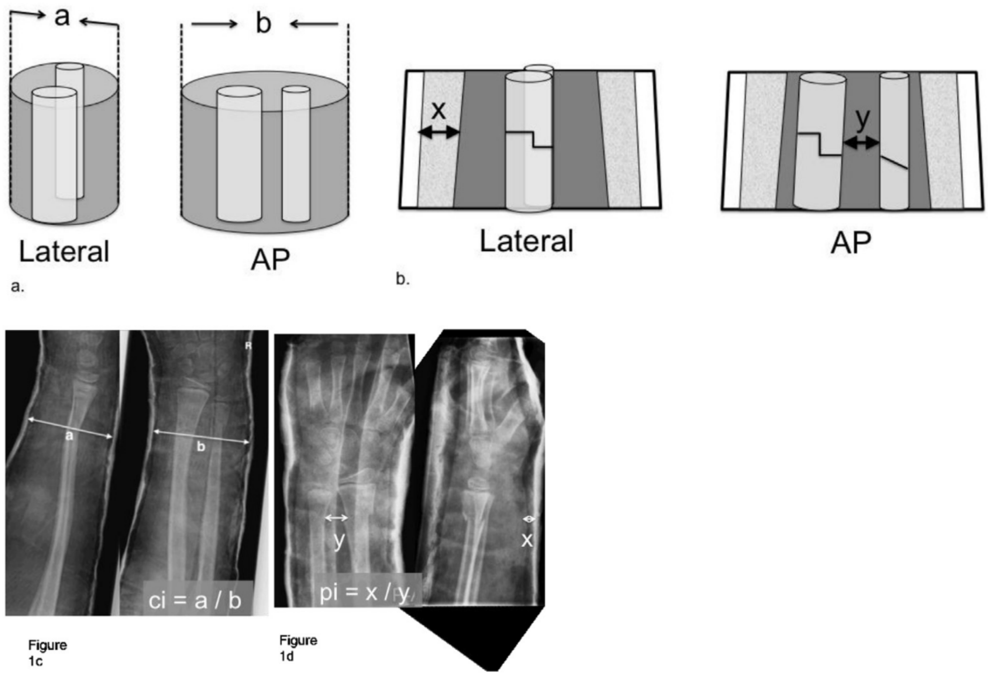


**Fig. 1.** 1a and 1b Cast index (a/b) at fracture site. Internal cast width on radiograph (a) and internal cast width on AP radiograph (b). Fig. 1c and d Padding index (x/y). Padding thickness in the plane of deformity correction on lateral radiograph (x) and maximum interosseous space on AP radiograph (y).


**Fig. 2.** Severity of the fracture defined as a. 1 cortex, b. 2 cortices or c. complete fracture displacement.

Complete fracture displacement of the ulna occurred in 14 (64%) patients in the reduction loss group and gave an odds ratio of 16.4 for the likelihood of developing loss of reduction. An average displacement of 51% of the ulnar fracture width was seen in the reduction loss group versus an average of only 3% in the group with no reduction loss. In one case this complete displacement of the ulnar fracture occurred in combination with a greenstick fracture of the radius, in all others it was concomitant with displacement of the radial fracture. Although high odds ratios were observed for displacement of the ulnar fracture in univariate analysis, multivariate analysis excluded it as a significant risk factor. In fact, all significant factors but fracture displacement of the radius were excluded by multivariate analysis.

Residual angulation did not differ between groups (6° vs 5°, $p = 0.55$). Almost half (21 patients) of the total population had a residual angulation of less than 5°; highest residual angulation was 15°. The mean residual fracture displacement of the total population was 10%, with 42% of these participants showing a residual fracture displacement varying from 10 to 50%. The residual fracture displacement was nonetheless significantly worse in the group with loss of reduction ($p = 0.022$). In this group, 13 (59%) cases had residual fracture displacement (e.g. less than 100% bone contact), with a mean of 14% of the radial width (Table 3). A residual fracture displacement of 0–20% gave a 4.8 likelihood of losing reduction, and in the group with residual fracture displacement of >20% this increased to 8.1. Also, residual fracture displacement in the frontal plane gave a higher likelihood (OR 7.9) of losing reduction than residual fracture displacement in the sagittal plane (OR 2.4). One case was subjected to corrective surgery due to increasing fracture displacement. Re-manipulation occurred in three patients.

The cast index was not significantly different between groups (0.91 vs 0.92, $p = 0.77$) (Table 4). Padding index was worse in the group without loss of reduction (0.58 vs 0.39, $p = 0.15$). Good limits of agreement were seen for both indices (Tables 5 and 6).

## 4. Discussion

This study was designed to determine and confirm predictors of alignment loss after a successful reduction and cast immobilisation in forearm fractures. We specifically focused on angulated and displaced paediatric both-bone forearm fractures, as these fractures have less intrinsic stability than isolated radial fractures. We hypothesised that the chances of losing alignment in reduced fractures would be influenced by initial angular deformation; initial fracture displacement; number of fractured cortices; residual angulation; residual fracture displacement; obtained stability and cast and padding index.

This study stresses the most important risk factors for alignment loss. This is why children with a reduced BBFF who lost reduction during conservative treatment were studied and compared with a control group with less than 5° variance between post-reduction control radiograph and cast radiograph. We considered 5° as a standard error of measurement between radiographs an acceptable cut-off value for selection of our control group.[30,31] This control

**Table 2**
Fracture characteristics.

| Mean/median/n (SD/ICR/%) | Total (n = 38) | Group A loss of reduction (n = 22) | Group B no loss of reduction (n = 16) | p-value |
|---|---|---|---|---|
| Proximity (n) | | | | |
| Distal | 26 (68%) | 16 (73%) | 10 (63%) | 0.58 |
| Midshaft | 11 (29%) | 6 (27%) | 5 (31%) | |
| Proximal | 1 (3%) | 0 (0%) | 1 (6%) | |
| Direction of angulation (n) | | | | |
| Dorsal | 34 (89%) | 22 (100%) | 12 (75%) | 0.025 |
| Volar | 4 (11%) | 0 (0%) | 4 (25%) | |
| Radial or ulnar deviation (n) | 9 (24%) | 7 (32%) | 2 (12.5%) | 0.25 |
| Angulation of trauma (degrees) | 24 (SD 7) | 26 (SD 5) | 23 (SD 8) | 0.18 |
| Number of radial cortices (n) | | | | |
| 1 cortex | 17 (45%) | 6 (27%) | 11 (69%) | <0.001 |
| 2 cortices | 6 (16%) | 2 (9%) | 4 (25%) | |
| Complete fracture displacement | 15 (39%) | 14 (64%) | 1 (6%) | |
| Fracture displacement, radius (%) | 37 (SD 46) | 62 (SD 46) | 4 (SD 12) | <0.001 |
| | n = 17 (45%[a]) | n = 15 (68%[a]) | n = 2 (13%[a]) | |
| Radial shortening (n) | 11 (29%) | 11 (50%) | 0 (0%) | <0.001 |
| Number of ulnar cortices (n) | | | | |
| 1 cortex | 17 (45%) | 6 (27%) | 11 (69%) | 0.012 |
| 2 cortices | 10 (26%) | 6 (27%) | 4 (25%) | |
| Complete fracture displacement | 11 (29%) | 10 (45%) | 1 (6%) | |
| Fracture displacement, ulna (%) | 30 (SD 44) | 51 (SD 48) | 3 (SD 8) | <0.001 |
| | n = 17 (45%[a]) | n = 15 (68%[a]) | n = 2 (13%[a]) | |
| Ulnar shortening (n) | 9 (24%) | 9 (41%) | 0 (0%) | 0.005 |

[a] Percentage of the group with any initial fracture displacement. The remaining part of the group had no fracture displacement.

**Table 3**
Post-reduction characteristics (angulation in degrees, displacement in percentage).

| Mean/median (SD/ICR) | Total (n = 38) | Group A loss of reduction (n = 22) | Group B no loss of reduction (n = 16) | p-value |
|---|---|---|---|---|
| Residual angulation (degrees) | 5 (SD4) | 6 (SD 5) | 5 (SD 3) | 0.55 |
| Residual fracture displacement (%) | 10 (SD 14) | 14 (SD 15) | 4 (SD 11) | 0.022 |
| | n = 16 (42%[a]) | n = 13 (59%[a]) | n = 3 (19%[a]) | |
| Angulation 1 week (degrees) | 10 (SD8.24) | 13 (SD 9) | 6 (SD 4) | 0.007 |
| Angulation 2 weeks (degrees) | 12 (7–19) | 17 (12–22) | 6 (4.5–9) | <0.001 |
| Angulation 4 weeks (degrees) | 10 (SD 7) | 17 (SD 6) | 5 (SD 3) | <0.001 |
| Angulation 8 weeks (degrees) | 15 (7–22) | 20 (11–22) | 3 (1–5) | <0.001 |
| Angulation 1 year (degrees) | Angulation 1 year (degrees) | Angulation 1 year (degrees) | Angulation 1 year (degrees) | Angulation 1 year (degrees) |

[a] Percentage of the group with any residual fracture displacement. The remaining part of the group had no residual fracture displacement.

group was used to identify and confirm the factors considered important for alignment loss.[4,21,24,26,32,33]

In this study, complete fracture displacement (bayonet apposition) of the radius proved to be a considerable risk factor, which can be confirmed by current literature.[4,21,24,26,32,33] Both complete fracture displacement and shortening of the radius were found to be significantly greater in the group with loss of reduction. Complete displaced BBFFs or shortened BBFFs are therefore more prone to losing alignment than greenstick fractures or those that are completely fractured and not 100% displaced or shortened. This phenomenon can be explained by a lack of periosteal hinge, which affects stability in complete displaced fractures. Others state that the risk of loss of reduction is already increased from an initial translation of 50% with a 60% probability of treatment failure.[19,34] Initial fracture displacement of more than 50% can impede, probably by interposition, the treating surgeon from performing an anatomic reduction. In addition, the number of reduction attempts can damage the periost and cause more severe soft-tissue swelling in these types of fractures. The latter can contribute to an increased chance of reduction loss while the cast loses its fit.

Complete fracture displacement and shortening of the ulna were significantly different between groups and suggest a role of associated ulnar fractures in the rate of reduction loss; this could not be found in literature.[1,2,17,21,26,35,36] Some authors even claim that isolated distal radial fractures are less stable and prone to lose alignment.[1,35,36] As was found in other studies, complete fracture displacement of the ulna was closely related with complete fracture displacement of the radius, which a priori disrupts stability and increases the risk of losing reduction.[24,32,37]

The second most important risk factor found for alignment loss is the inability to obtain anatomic reduction.[5,19,21,33] Incomplete reduced fractures are five times more susceptible to redisplacement than those in which anatomic reduction is obtained.[16,17,21,24,32,33] This could be confirmed in previous research, independently of fracture severity.[32] Few authors have evaluated independently the influence of residual angulation and residual fracture displacement though.[26,36] Residual angulation after reduction was equal in both these studied groups. The adequacy of reductions seemed acceptable: 56% of all fractures had a residual angular deformity of less than 5° and the highest residual angulation was 15°.

Residual fracture displacement, however, was significantly different between the groups. The majority of patients in the reduction loss group had residual fracture displacement (i.e. loss of bone contact), in contrast to the group that retained reduction. Based on these results we conclude that residual fracture displacement, especially in the AP view, is of greater influence on loss of reduction than residual angulation. The inability to obtain anatomic reduction is suggested in the literature to be the second most-found risk factor for alignment loss, yet for angulation this

**Table 4**
Univariate exact logistic regression analysis (influence of risk factors on the likelihood of loss of reposition).

| | Odds ratio | 95% confidence interval for odds ratio | p-value[a] |
|---|---|---|---|
| Fracture displacement, radius (relative to 1 cortex) | | | |
| 2 cortices | 0.920 | 0.065 to 8.948 | 1000 |
| Complete fracture displacement | 22.82 | 2.413 to >999 | 0.002 |
| Fracture displacement, radius (relative to no fracture displacement) | | | |
| 1–100% | 3784 | 0.422 to 51.67 | 0.321 |
| 100% | 25,527 | 4.579 to Infinity | <0.001 |
| For each percent of radial fracture displacement | 1052 | 0.892 to 1.249 | 0.564 |
| Radius shortening (relative to no shortening) | 19.68 | 3.644 to Infinity | 0.001 |
| Fracture displacement, ulna (relative to 1 cortex) | | | |
| 2 cortices | 2644 | 0.425 to 18.68 | 0.398 |
| Complete fracture displacement | 16,369 | 1.649 to 865.8 | 0.009 |
| Fracture displacement, ulna (relative to no bayonet apposition) | | | |
| 1–100% | 4698 | 0.586 to 61.342 | 0.187 |
| 100% | 23.15 | 4.118 to Infinity | <0.001 |
| Ulnar shortening (relative to no shortening) | 13.76 | 2.517 to Infinity | 0.006 |
| Residual fracture displacement, radius (relative to no displacement) | | | |
| On anteroposterior radiograph | 7928 | 1.323 to 88.46 | 0.018 |
| On lateral radiograph | 2419 | 0.450 to 17.25 | 0.415 |
| 0–20%[b] | 4783 | 0.692 to 57.799 | 0.136 |
| >20%[b] | 8070 | 0.774 to 428.5 | 0.098 |

Other variables not mentioned in this table were found to be not significant.
[a] Two-sided.
[b] Division based on amounts (numbers).

**Table 5**
Cast index and padding index.

| Median (ICR) | Total (n = 38) | Group A loss of reduction (n = 22) | Group B no loss of reduction (n = 16) | p-value |
|---|---|---|---|---|
| Cast index | 0.91 (0.87–0.98) | 0.91 (0.87–0.98) | 0.92 (0.88–0.98) | 0.77 |
| Padding index | 0.40 (0.31–0.54) | 0.39 (0.31–0.48) | 0.44 (0.31–0.77) | 0.15 |

**Table 6**
Agreement of cast index and padding index (according to Bland-Altman method).

| | Mean difference | 95% Confidence interval | Limits of agreement | 95% Confidence interval (lower and upper limit) |
|---|---|---|---|---|
| Cast index | 0.017 | −0.006 to 0.039 | −0.102 to 0.135 | −0.140 to −0.063<br>0.096 to 0.173 |
| Padding index | 0.057 | −0.019 to 0.133 | −0.346 to 0.460 | −0.477 to −0.214<br>0.329 to 0.592 |

could not be observed in our study data.

In this study neither the cast index nor the padding index were significantly different between groups. The mean cast index was 0.94, while in literature it is stated that a cast index of more than 0.80 predisposes fractures to lose reduction.[18,37,38] In all but one subjects the measured cast index exceeded 0.80. This one subject did maintain the reduction. The padding index was also rather high, with only 19% scoring under the ideal index of 0.30. It can be stated that, regardless the quality of casting, other risk factors such as initial and residual fracture displacement after reduction contribute to reduction loss. This is supported by research with varying results on the predictive value of padding index, cast index and other radiological indices.[19,21,25,26,36–39]

Although not significant, the greatest initial angulation tended to be even slightly worse in the group that maintained reduction. The most logical explanation for this finding is that greenstick fractures, which were significantly more present in the control group, tend to angulate more than complete fractures, because the partially intact and plastically deformed cortex allows them to.[18,24]

We acknowledge some limitations of this study. The exact moment at which the fractures lost their reduction could not be assessed, as radiographs were taken at determined moments and no pre- and post-casting radiographs were taken. Neither type of anaesthesia nor number of reduction attempts were examined, since these specifics were not documented in most cases. A larger number of subjects would have yielded a more accurate analysis and perhaps a more contributing multivariate analysis. Distal and diaphyseal fractures could have been evaluated individually, as these are essentially different fractures.

Because the need for a secondary procedure in complete displaced distal radius fractures can be as high as 21.2% when treated with reduction and cast immobilisation alone,[2,32] many authors prefer initial surgical management in this type of fracture.[2,5,17,26,34,39] The incidence of reduction loss can be lowered considerably by surgically adding stability to those fractures that are most prone to lose reduction.[2,40]

The results of this study showed that fractures with initial complete fracture displacement and any residual fracture displacement (>0%) are prone to lose reduction and require a more frequent follow-up schedule, or even a more initial stable surgical treatment regime.

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All the authors were actively involved in the planning and enactment of the study, and assisted with the preparation of the submitted article:

- Authorship is based on 1) substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; 2) drafting the article or revising it critically for important intellectual content; and 3) final approval of the version to be published. The authors meet conditions 1, 2, and 3.
- All persons designated as authors are qualified for authorship, and they are all listed.
- Each author has participated sufficiently in the work to take public responsibility for appropriate portions of the content.
- The article has not been submitted elsewhere.
- All authors disclose any financial and personal relationships with other people or organisations that inappropriately influence (bias) the work related to this draft.

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