Title: Measuring deformational plagiocephaly and brachycephaly using a smartphone in a prospective study

Authors: Can Kocabalkanli, Fereshteh Aalamifar, Regina Fenton, Susan Gaetani, Marius George Linguraru, Reza Seifabadi

Background & Purpose: Deformational plagiocephaly and brachycephaly (DPB) is a cranial condition manifested in 20% of infants in the US. DPB affects children and their families through psychological pressure, social stigma, and significant medical costs. If detected between 0-3 months of age, there is strong potential for correction via aggressive repositioning and/or physical therapy if congenital muscular torticollis is present. At later stages, DPB is most effectively treated by more expensive treatments like helmet therapy. Two cranial parameters that can help with the early detection and tracking of DPB are the cranial index (CI) and cranial vault asymmetry index (CVAI). Currently, these measurements are performed with a hand caliper by a specialist, i.e., nurse practitioner (CRNP) or physician assistant who specializes in cleft-craniofacial diagnosis, physical therapist, pediatric plastic/neurosurgeons, or orthotist. To make the measurements frequent, accessible, and accurate at the point of care, i.e., in pediatric offices, we developed and evaluated a mobile app called Softspot^{TM} to measure CI and CVAI, thus facilitating the early detection and monitoring of DPB.

Method/Description: Sequences of bird's eye-view head photos extracted from video were collected for 77 patients (aged 2 – 11 months, 51 females, 26 males) with an iPhone X (Apple Inc., Cupertino, CA). The head length, width, and diagonals were measured by a single CRNP via hand calipers at a large multidisciplinary cranio-facial center with IRB approval and patient consent. For each patient, five images were chosen by an analyst and segmented into head components, namely the head and nose, using quantitative imaging methods. For each image CI and CVAI were automatically measured, and these measurements were averaged for each patient. Automated CI and CVAI measurements were compared to values obtained by the caliper measurements in terms of mean absolute error (MAE), and outliers were excluded beyond 3 standard deviations away from the average MAE. Results were further analyzed by the Bland-Altman method and Spearman Correlation Coefficient.

Results: MAE was 2.18 ± 1.60 for CI and 1.57 ± 1.03 for CVAI measurements. Spearman Correlation Coefficients between measurements and ground truth were 0.93 for CI ($p<0.001$) and 0.91 for CVAI ($p<0.001$). Bland-Altman analysis revealed limits of agreement for CI and CVAI as [-4.59, 5.76] (mean = 0.59) and [-3.91, 3.40] (mean = -0.25) respectively.

Conclusions:-Digital smartphone-based methods for DPB assessment are feasible, and this study demonstrated significant correlation between automated digital measurements and ground truth clinical values. Smartphone-based measurements of DPB can be performed at the point of care to improve the early detection and treatment of DPB.

Error and Correlation Characteristics

Measurement	MAE	Std. Dev.	Spearman	R^2
CI	2.18	1.60	0.93	0.86
CVAI	1.57	1.03	0.91	0.90

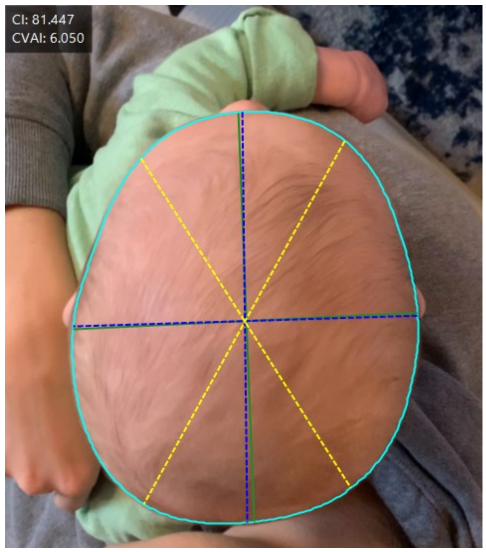

Figure 1: Calculating CI and CVAI from the image of a patient's head

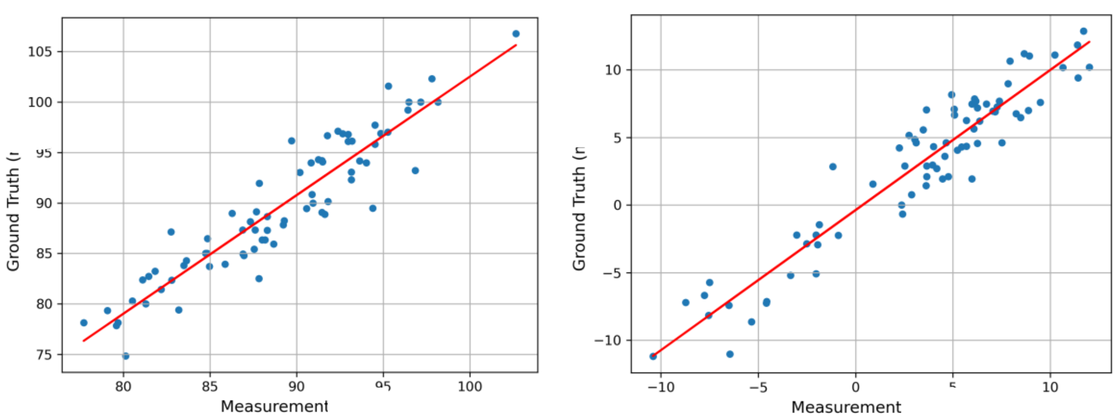

Figure 2: Correlation Plots: CI (left), CVAI (right)

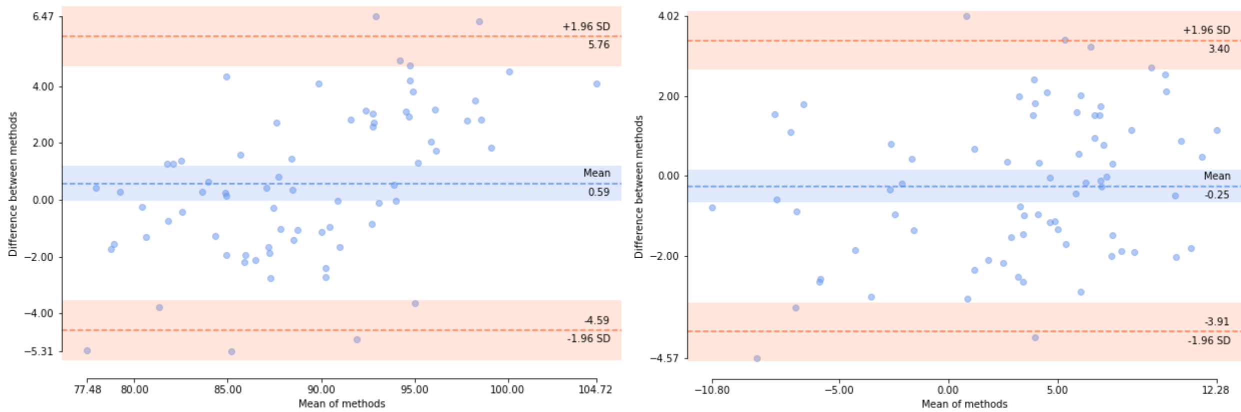

Figure 3: Bland-Altman Plots: CI (left), CVAI (right)