Analysis of Cranial Type Characteristics in Term Infants: A Multi-center Study

Yang Wang
The Second Affiliate Hospital of Army Medical University
Hu Bin
The Second Affiliate Hospital of Army Medical University
Chen Jianping
Chongqing Health Center for Women and Children
Shen Wenzhi
Wanzhou Maternal and Child Health Care Hospital of Chongqing
Wang Chengju
The Second Affiliate Hospital of Army Medical University
Chang Qin
The Second Affiliate Hospital of Army Medical University
Li Wenzao
The Second Affiliate Hospital of Army Medical University
Qu Fuxiang
The Second Affiliate Hospial of Army Medical University
Pan Qiuming
The Second Affiliate Hospital of Army Medical University
Zhang Yuping (yupingzhang@tmmu.edu.cn)
The Second Affiliate Hospital of Army Medical University

Research article

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Abstract

Background: Positional head deformity (PHD) is defined as a change in the shape of a baby's skull due to external force. In certain cases, it can lead to cosmetic deformities or even neurological issues due to its impact on the developing nervous system. We therefore conducted this study to investigate the incidence and characteristics of PHD in term infants in China and preliminarily establish a localized diagnostic reference standard.

Methods: Overall, 4456 term infants from three medical institutions in Chongqing were recruited and divided according to age groups. Cranial vault asymmetry (CVA) and cephalic index (CI) were calculated in all infants. The current international diagnostic criteria were used to understand PHD incidence and analyze their CVA and CI distribution.

Results: According to the current international standards, the total detection rate of PHD in Chongqing's term infants was 81.5%, with brachycephaly alone being the most frequent (39.4%), followed by brachycephaly with plagiocephaly (34.8%), and plagiocephaly alone (6.2%). The detection rates of dolichocephaly were low: alone, 0.9% and combined with plagiocephaly, 0.2%. According to age, plagiocephaly (44.5%) and brachycephaly (82.0%) were most frequent in the 2-3-month group. The 75th/90th/97th percentiles and 3rd/10th/25th/75th/90th/97th percentiles of CVA and CIs were 0.4/0.7/1.0 and 76.4/78.8/82.3/91.1/94.6/99.2%, respectively.

Conclusion: According to the current international standards, the PHD detection rate among term infants in Chongqing was high. Therefore, a new diagnostic standard for Chinese infants was proposed. CVA ≥0.4 cm indicates plagiocephaly. CI ≥91% indicates brachycephaly. CI ≤82% indicates dolichocephaly.

Background

Positional head deformity (PHD) refers to changes in the shape of a baby's skull in the front, back, or sides due to external force. PHD can lead to cranial or facial unsightliness, resulting in the child developing an inferiority complex and even being bullied by other children. Serious PHD may also be combined with impaired nervous system development and cognitive function, resulting in intellectual disabilities, learning difficulties, and/or language disorders (1,2). PHD is a common problem in the first 6 months of life and is present in 20%-46% of live births (3). The earlier the discovery of PHD, the better the effect of the intervention and the lower the cost. Especially in the PHD of 3-month-olds, the best correction effect can be achieved simply by adjusting the sleeping posture (4). After 6 months of age, the growth rate of the baby's skull decreases, the hardness of the skull and the free movement of the head increases; therefore, PHD generally does not continue to progress; however, treatment difficulty also greatly increases compared to that before 6 months of age (5). Therefore, the key period for prevention and management of PHD is before 6 months of age.

PHD can be divided into three types, according to head shape: 1) plagiocephaly, wherein due to uneven stress on both sides of the skull, one side of the skull is compressed and tilted, resulting in an increase in the difference between the skull’s diagonals; 2) brachycephaly, also known as flat head, refers to the flat shape of the skull, with an increased ratio of the head width to length; and 3) dolichocephaly, wherein the diameter of the front and back of the skull is significantly larger than the left and right diameter, resulting in a long and narrow head shape (6).

The criteria for the diagnosis and severity of PHD can be determined using quantitative indexes. The two main indexes for PHD diagnosis are cranial vault asymmetry (CVA) and cephalic index (CI). Previous researchers have stated that the diagnostic standards of plagiocephaly, brachycephaly, and dolichocephaly were CVA ≥0.3%, CI ≥82%, and CI ≤76%, respectively (based on research using vision, anthropometry, and digital photographic tracking technology) (1,7,8). These are now the most widely used diagnostic standards for determining PHD type and degree globally. However, owing to large differences in the basic infant cranial types among different regions and races, it is inappropriate to diagnose infant PHD using only this standard. For example, Graham et al. (9) reported that CI values for Asian children’s skulls were significantly higher than those for their international counterparts. In China, due to the impact of socioeconomic problems and insufficient knowledge of PHD, people lack awareness of the harm it causes. Furthermore, there have been few relevant clinical studies, and no diagnostic standard established is suitable for PHD among Chinese infants, which means diagnosis and prevention miss the most effective treatment period (10).

Therefore, we collected the cranial type measurements of term infants in children's health clinics from three medical institutions in Chongqing. First, we used the current international general diagnosis standard of PHD to measure the PHD incidence among term infants, and then analyzed the cranial type characteristics. Accordingly, we presented preliminarily localized diagnosis and severity reference values for plagiocephaly, brachycephaly, and dolichocephaly, hoping to facilitate the early prevention and intervention of PHD in China.

Methods

Research subjects

We enrolled 4456 term infants up to 6 months old who visited the outpatient departments of the primary care clinic of Xinqiao Hospital, Army Medical University, and the Maternal and Child Health Care Hospitals of Wanzhou and Yongchuan in Chongqing from September 1, 2017, to August 31, 2019. They were divided into the 0-1, 2-3, and 4-5 months age groups, and data were collected once per infant. The inclusion criteria were: (1) gestational age at birth of 37-42 weeks; (2) single birth; and (3) appropriate for gestational age. We excluded: (1) patients diagnosed with brain injury, dysplasia, or global developmental delay within 6 months, (2) infants with congenital muscular torticollis, and (3) infants with cranial abnormalities due to definite craniosynostosis.

The study was approved by the ethics committee of the Second Affiliated Hospital of the Army Medical University (Ethics approval number: 2016-[illegible]024–01). Informed written and verbal consent was obtained from the infants' parents or guardians. The trial was performed in accordance with the approved guidelines and regulations of the participating institutions.

Measurement

The manual measurement method of Wilbrand et al.'s standardization scheme was adopted (11). The measurement tool was the KWJ124 bending foot gauge (size 260 ×260 + 36 mm), the measurement range was 0-300 mm, and the executive production standard was GB5704.3-85.

Survey personnel were intensively trained before the test. According to the reliability test, the measurement difference of all survey personnel was less than 5%; each parameter was measured thrice per patient and the mean value was analyzed.

The examiner held the infant's head in a centered position while the infant faced the examiner. The standard measurement scheme requires the following: (1) transcranial oblique diameter is the distance from the middle point of the temporal ridge of frontal bone to the inner edge of the contralateral herringbone suture, the long diameter is diagonal A (DA), the short diameter is diagonal B (DB); (2) head length is the distance from the glabella to the farthest point (opisthocranion, op); and (3) head width is the distance between two points 1 cm higher than the attachment point of both ears. All measuring lines were parallel to the Frankfurt line (12).

Using these values, the following were calculated: CVA = difference of the oblique diameter on both sides of the head (CVA = DA-DB); CI = ratio of the maximum transverse diameter of the cranial to the maximum fore-and-aft diameter (CI = cranial width/cranial length×100%).

Diagnostic criteria

Diagnostic criteria were based on the *Handbook of Physical Measurements* and current international standard for PHD diagnosis (1,7-8, 13-14) (Table 1).

Table 1. Diagnostic criteria of type and severity of positional head deformity

	Plagiocephaly (CVA)	Brachycephaly (CI)	Dolichocephaly (CI)
Mild	3-10 mm	82-90%	74-76%
Moderate	10-12 mm	90-100%	70-74%
Severe	>12 mm	>100%	<70%

CVA, cranial vault asymmetry; CI, cephalic index

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics 22.0 for Windows (IBM Germany GmbH). Measurement data are represented as mean±standard deviation. The differences of mean among groups were analyzed using the one-way analysis of variance, and the comparisons of count data between groups were tested using the chi-square test.

Results

Patient characteristics

A total of 4456 term infants were enrolled (0-1 month: 1628, 2-3 months: 1506, 4-5 months: 1322). General characteristics of each group are shown in Table 2. There were no significant differences in average gestational age, birth weight, sex, and delivery type.

Table 2. General characteristics of term infants

	0-1 months	2-3 months	4-5 months	Statistical value
n	1628	1506	1322	
Gestational age ($x \pm s$, w)	39.1±2.2	38.9±1.7	39.2±0.9	F=2.926, P=0.4152
Birth weight ($x \pm s$, kg)	3.22±0.46	3.19±0.71	3.22±0.38	F=1.876, P=0.2659
Sex (Male/female, *n*)	801/827	724/782	623/699	χ^2=2.240, P=0.617
Delivery type (natural birth/cesarean section, *n*)	873/755	776/730	701/624	χ^2=1.983, P=0.752

Cranial patterns according to the current international general standard

According to the current international standard, of the 4456 term infants, 3632 cases (81.5%) of PHD were detected and only 824 normal cranial types (18.5%). In the classification of abnormal skull type, the detection rate of brachycephaly alone was the highest (1756 cases, 39.4%), followed by brachycephaly combined with plagiocephaly (1551 cases, 34.8%), and plagiocephaly alone (276 cases, 6.2%), while dolichocephaly alone (41 cases, 0.9%) and dolichocephaly combined with plagiocephaly (8 cases, 0.2%) were relatively low (Figure 1).

Plagiocephaly in each age group

According to the current international standards, the total number of researched infants with plagiocephaly was 1835 (41.2%). The detection rate of plagiocephaly in the 0-1-month group (35.9%) was significantly lower than that among the 2-3 (44.5%) and 4-5 months groups (43.9%). There were no significant differences between 2-3 and 4-5 months groups. Regarding the severity of plagiocephaly, mild plagiocephaly was the highest in each age group, and the detection rate of mild, medium, and severe plagiocephaly in the 2-3 and 4-5 months groups were significantly higher than those in the 0-1 month group; however, there were no significant differences in the detection rate of each degree of plagiocephaly between the 2-3 and the 4-5 months groups (Table 3).

Table 3. Plagiocephaly severity in term infants of different age groups

Group (age, months)	*n*	CVA (cm)	Plagiocephaly	Severity		
				Mild	Medium	Severe
0-1	1628	0.27±0.25	584 (35.9%)	550 (33.8%)	24 (1.5%)	10 (0.6%)
2-3	1506	0.37±0.29	670 (44.5%)*	614 (40.8%)*	32 (2.1%)*	24 (1.6%)*
4-5	1322	0.34±0.29	581 (43.9%)*	517 (39.1%)*	35 (2.6%)*	29 (2.2%)*

Note: * significant difference compared to the 0-1 month group (P<0.05)

CVA, cranial vault asymmetry

Brachycephaly in each age group

According to the current international standards, the total number of researched infants with brachycephaly was 3307 (74.2%). The detection rate in the 0-1 month group (66.1%) was significantly lower than that in the 2-3 (82.0%) and 4-5 months groups (75.3%). There were no significant differences between the 2-3 and 4-5 months groups. Regarding the severity of brachycephaly, mild brachycephaly was the highest in each group. Medium and severe brachycephaly in the 2-3 and 4-5 months groups were significantly higher than those in the 0-1 month group, while the detection rate of mild brachycephaly was lower than that in the 0-1 month group. There were no significant differences between the 2-3 and the 4-5 months groups (Table 4).

Table 4. Brachycephaly severity in term infants of different age groups

Group (age, months)	*n*	CI (%)	Brachycephaly	Severity		
				Mild	Medium	Severe
0-1	1628	84.4±5.4	1076 (66.1%)	827 (50.8%)	241 (14.8%)	8 (0.5%)
2-3	1506	88.0±6.6	1235 (82.0%)*	671 (44.6%)*	514 (34.1%)*	50 (3.3%)*
4-5	1322	88.4±6.0	996 (75.3%)*	566 (42.8%)*	390 (29.5%)*	40 (3.0%)*

Note: * significant difference compared to the 0-1 month group (P<0.05)

CI, cephalic index

Dolichocephaly in each age group

According to the current international standards, the total number of researched infants with dolichocephaly was 49 (1.1%). There were no significant differences in the detection rate of dolichocephaly among all age groups. In terms of the severity of dolichocephaly, mild dolichocephaly was dominant in all age groups, and no severe cases were detected (Table 5).

Table 5. Dolichocephaly severity in term infants of different age groups

Group (age, months)	*n*	Dolichocephaly	Severity		
			Mild	Medium	Severe
0-1	1628	16 (1.0%)	14 (0.9%)	2 (0.2%)	0
2-3	1506	19 (1.2%)	16 (1.1%)	3 (0.2%)	0
4-5	1322	14 (1.1%)	12 (0.9%)	2 (0.2%)	0

Left and right plagiocephaly

Among the 1835 term infants diagnosed with plagiocephaly, right plagiocephaly (69.5%) was significantly higher than left (30.5%) overall, and that in each age group (Figure 2).

Percentile distribution of CVA and CI

The percentile method was used for analysis, and the percentile distribution of CVA and CI values grouped by age is shown in Table 6. The percentages of 75th (P75)/90th (P90)/97th (P97) percentiles and CI values of 3rd (P3)/10th (P10)/25th (P25)/50th (P50)/P75/P90/P97 percentiles are 76.4/78.8/82.3/86.7/91.1/94.6/99.2%, respectively.

Table 6. Percentile distribution of CVA and CI in term infants

Percentile	0-1 months		2-3 months		4-5 months		0-5 months	
	CVA	CI	CVA	CI	CVA	CI	CVA	CI
3	0.0	74.8%	0.0	77.3%	0.0	78.6%	0.0	76.4%
10	0.1	77.4%	0.1	79.7%	0.1	80.6%	0.1	78.8%
25	0.1	80.1%	0.2	83.9%	0.1	83.8%	0.1	82.3%
50	0.2	84.7%	0.3	88.3%	0.2	87.8%	0.2	86.7%
75	0.4	88.3%	0.5	92.3%	0.5	92.7%	0.4	91.1%
90	0.5	91.7%	0.7	96.3%	0.7	96.8%	0.7	94.6%
97	0.9	93.8%	1.1	100.0%	1.0	101.5%	1.0	99.2%

CVA, cranial vault asymmetry; CI, cephalic index

Discussion

Since the American Academy of Pediatrics advocated "supine sleep" in the 1990s, the incidence of sudden infant death syndrome has decreased significantly, but the incidence of PHD has increased significantly (5). Since then, PHD has been widely studied. In 2001, Boere-Boonekamp et al. (15) reported a PHD detection rate of 8.2% in 7609 infants younger than 6 months of age in the Netherlands, while in 2013, Mawji et al. (16) found that PHD detection rate in 7-12 week-old healthy term infants in Canada was 46.6%. However, to the best of our knowledge, there are no detailed statistical and analytical reports on infant cranial type in China.

In our results, PHD incidence among 4456 term infants in Chongqing is 81.5% (Figure 1) when using the international general diagnosis standard. Among them, incidence of plagiocephaly (44.5%; Table 3) and brachycephaly (82.0%; Table 4) was the highest in the 2-3 month group is the highest, suggesting that the PHD incidence gradually increases up to 2-3 months after birth, before gradually declining. This is because the baby’s head is not vertically stable up to 3 months after birth, and caregivers usually place the baby in a supine position, where the occipital force is greater, leading to a higher incidence of brachycephaly, while the incidence of dolichocephaly is lower (Table 5). In addition, at this stage, the baby's ability to keep their head centered is poor. If the head is inclined when supine, long term compression of the side of the skull results in plagiocephaly. At 4 months of age, head control improves, time spent outside the bed increases and uneven stress of the skull reduces, so further aggravation of PHD decreases. Therefore, the first 4 months after birth is the key period for monitoring cranial shape, which should be measured monthly. Early detection of PHD and corresponding correction are often effective.

In addition, this study found that the detection rate of right plagiocephaly in term infants of each age group was significantly higher than that of left (Figure 2), which was consistent with the findings of Kluba et al. (17). This may be because the apex of most fetal heads in the womb are located in the birth canal, with the left occipital side in front, so that the right occipital bone is pressed on the woman's pelvis and the left forehead is in contact with the lumbosacral vertebrae. This is likely to continue after childbirth due to sleeping posture, because babies preferentially turn their heads to the right side to be comfortable, thus aggravating the deformity on the right side (16).

The present study also found that according to international general diagnostic standards, brachycephaly was frequent among the studied term infants. The rate of brachycephaly at the age of 2-3 months is 82.0%, which is much higher than that reported by Ballardini et al. (18), while the rate of plagiocephaly (44.5%) is similar to that reported by Mawji et al. (46.6%) (5), suggesting that the heads of infants in Chongqing are relatively flat. This relates to differences in parenting culture, customs, and esthetic preferences in different regions and nationalities. The flat baby head is in line with the esthetic views of Chinese parents. In traditional Chinese parenting habits, the baby is mainly placed in the supine position after birth, so their head shape is relatively flat. In contrast, CVA, used to diagnose oblique head deformity, reflects the different stress conditions of the left and right sides of the head; as the ideal of bilateral skull symmetry is shared by Chinese and international parents, little difference was seen regarding this aspect. There are obvious differences between the basic data of cranial types of infants in this region and internationally. Therefore, it is inappropriate to apply the commonly used international standards to diagnose infants' PHD in this region.

Regarding PHD diagnostic criteria, Hutchison et al. (13) set the brachycephaly threshold at CI ≥93% and plagiocephaly at CV ≥0.3 cm, while Loveday et al. (19) suggested that normal CI was 75%-85%, but none of these suggestions were based on the "norm" of comprehensive statistical analysis. At present, CVA ≥0.3 cm indicates plagiocephaly, CI ≥82% indicates brachycephaly, and CI ≤76% indicates dolichocephaly (1,7,8). In 2012, Wilbrand et al. (11) defined the graduation standard based on the measurement data of the European infant's skull type from the past 20 years, thus ignoring the regional differences (20). Relevant research in Asian regions is rare. Therefore, according to the present study, we consider the percentile P25 as the cutoff value for PHD, and P10 and P3 as the cutoff value for medium and severe PHD, respectively, and put forward preliminary reference values for PHD diagnosis in infants younger than 6 months of age in Chongqing (Table 6). CVA ≥0.4 cm indicates plagiocephaly (mild: 0.4 cm≤ CVA <0.7 cm [P75-P90], medium: 0.7 cm≤ CVA <1.0 cm [P90-P97], severe: CVA ≥1.0 cm [≥P97]). CI ≥91% indicates brachycephaly (mild: 91%≤ CI <95% [P75-P90], medium: 95%≤ CI <99% [P90-P97], severe: CI ≥99% [≥P97]). CI ≤82% indicates dolichocephaly (mild: 79%< CI ≤82%, medium: 76%< CI ≤79%, severe: CI ≤76%). The diagnostic standards for brachycephaly and dolichocephaly are quite different from the international standards, and are more suitable for the heads of Chinese babies and in line with Chinese parenting habits and esthetics. It is noteworthy that deviation from CVA or CI values in infants aged 1-2 months old is lesser than that in infants older than 2 months of age. Nonetheless, we include all infants aged up to 6 months when we recommend the diagnostic standard, mainly because lower complexity makes it more convenient for primary health care institutions to diagnose children. In addition, we referred to the current international diagnostic standard, which did not distinguish the diagnostic criteria of different months in detail. However, for the same reason, if a 0-1-month-old infant has developed medium or severe PHD, it suggests that the infant's head deformity may be more serious and the risk higher; hence, full attention should be paid to correcting it in time.

In the assessment, diagnosis, and treatment of infant cranial measurement and PHD, repeated measurement is needed, so the accuracy and convenience of measurement methods are important issues for clinical workers to consider. Carson et al. (21) state that visual assessment is the best diagnostic test tool, but visual assessment obviously relies on the personal experience and subjective judgment of the clinicians, which is not accurate enough either to quantify the degree of deformity or to make an objective assessment of the improvement after correction. The results of 3D laser and computed tomography can accurately and objectively determine the cranial type and correction effect, but are often time-consuming and labor-intensive; further, the radiation dose and cost must be considered (22). These are more suitable for children who need accurate head form assessment, such as children adjusting their helmet before or during helmet PHD correction treatment, or who need surgical treatment for craniosynostosis. This study adopts the manual measurement method based on Wilbrand et al. (11), which requires simple equipment, little time or effort, and can be used repeatedly. After training, the measurement values of different research centers can reach consistency, so it is an effective method suitable for use in primary health care institutions. However, in the process of using the bending foot gauge, there is a certain potential safety hazard if infants are crying or uncooperative, and special care should be taken.

The effectiveness of PHD correction is closely related to the growth rate of the skull (23). This grows rapidly before 6 months of age, and skull hardness is low. The earlier PHD is detected, the better the correction effect and the lower the treatment cost. However, after 6 months, hardness of the skull increases, growth speed of the head circumference decreases, and the therapeutic effect decreases significantly (24,25). Therefore, early screening, diagnosis, and intervention are important. This study is the first to analyze large measurement data samples of the cranial patterns of term infants in mainland China and propose preliminary local diagnostic reference standards according to the characteristics of the cranial patterns of Chinese infants. This will help the prevention and treatment of PHD in infants from this region and from China. However, China is vast and has significant regional differences in environment as well as ethnicity; it is therefore unclear whether the acquisition of major motor milestones by infants of different ethnicities has a direct impact on the development of cranial type (26). Future research should collect the cranio-type data of infants from different regions and races in China based on an in-depth understanding of PHD influencing factors and the growth and development process of skulls, to establish a unified Chinese standard.

List Of Abbreviations

CI: cephalic index

CVA: cranial vault asymmetry

PHD: positional head deformity

Declarations

Ethics approval and consent to participate

The study was approved by the ethics committee of the Second Affiliated Hospital of the Army Medical University (Ethics approval number: 2016-[illegible]024–01). Informed written and verbal consent was obtained from the infants' parents or guardians. The trial was performed in accordance with the approved guidelines and regulations of the participating institutions.

Consent for publication

Not applicable.

Availability of data and materials

The dataset being analyzed/used during the current study is available from the corresponding author on reasonable request.

Competing interests

The authors have no conflicts of interest to declare.

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Authors' contributions

Drs ZYP, HB, YW, CJP, and SWZ were involved in the study design. Drs WCJ, CQ, LWZ, QFX, and PQM contributed to the data collection. Drs YW and HB analyzed the data, wrote the first draft, and coordinated the writing of the subsequent drafts and the final version of the paper. Dr ZYP contributed to the review of all subsequent drafts of the paper. All the authors read and approved the final version of the paper.

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Figures

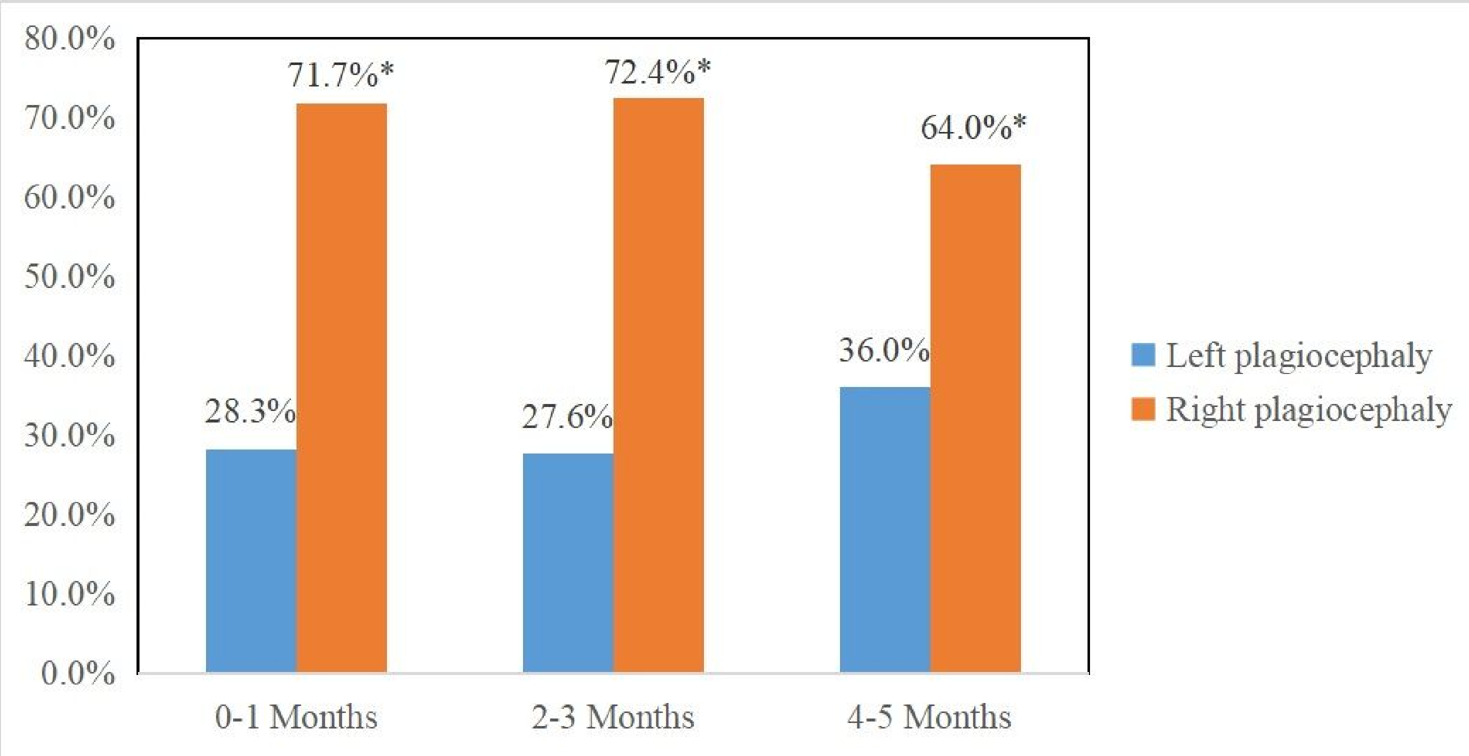

Figure 1

Distribution of cranial patterns in term infants (n, %)

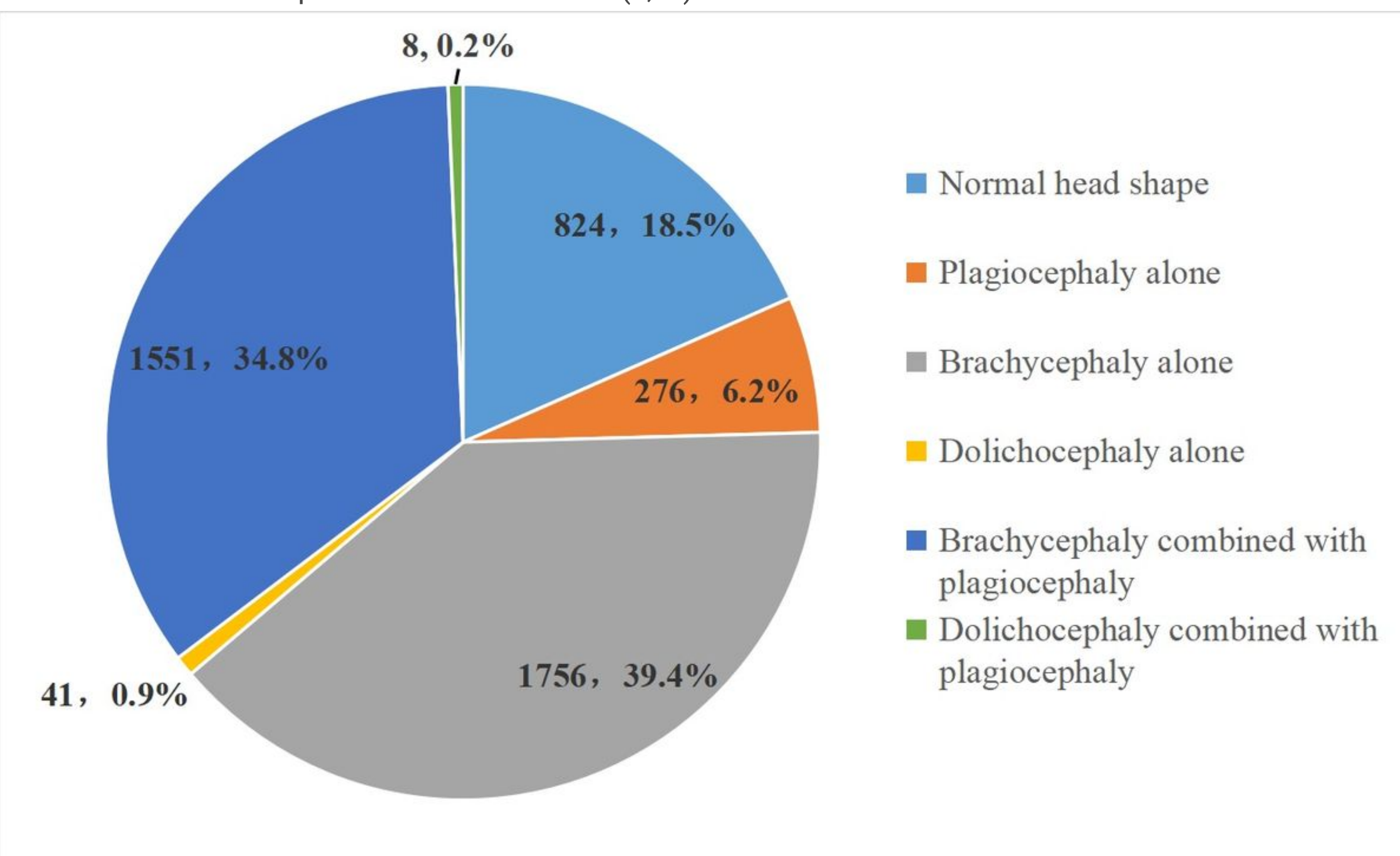

Figure 2

Left and right plagiocephaly in term infants in each age group