

Positional cranial deformities in paediatric rehabilitation: a retrospective cohort from a tertiary referral centre

Abstract

Background: Deformational cranial asymmetries are common in infancy and their prevalence has risen since supine sleep positioning was introduced; management ranges from repositioning and physiotherapy to cranial orthosis.

Objective: To characterise a paediatric cohort with deformational cranial asymmetries at a tertiary referral centre and describe craniometric evolution under a stepped conservative protocol.

Materials and methods: Retrospective study of children with a deformational cranial asymmetry diagnosed in the first year of life, assessed at a paediatric rehabilitation clinic during 2024. Craniometric measurements were obtained with a handheld craniometer by a single observer: the plagiocephaly index in plagiocephaly, and the cephalic index in brachycephaly and dolichocephaly. Complete resolution was defined as a final plagiocephaly index <5 mm.

Results: Forty-six patients were included, 26 (56.5%) male and 14 (30.4%) born preterm. Torticollis was present in 37 (80.4%). Diagnoses were plagiocephaly in 27 (58.7%), brachycephaly in 16 (34.8%) and dolichocephaly in 3 (6.5%). Median age at diagnosis was 2.5 months (IQR 1.0–4.0). Most patients were managed with repositioning alone (21, 45.7%) or with added physiotherapy (21, 45.7%); 4 (8.7%) required a cranial orthosis. Among 31 patients with paired measurements, the plagiocephaly index decreased from 6.0 to 4.0 mm ($p=0.037$; $r=0.37$), with complete resolution in 17 (54.8%; 95% CI 37.8–70.8%), and in 11 (50.0%) when restricted to baseline index ≥ 5 mm. Greater initial deformity correlated with a greater absolute reduction ($\rho=-0.44$; $p=0.014$) but a lower likelihood of resolution.

Conclusion: Referral occurred early, most children were managed conservatively, and only 4 (8.7%) required a cranial orthosis. Absence of a control group precludes attributing improvement to treatment.

Keywords: pediatrics, plagiocephaly, rehabilitation, cranial orthosis, torticollis, good health, well-being

Volume 11 Issue 3 - 2026

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Received: September 22, 2026 | **Published:** October 07, 2026

Introduction

Deformational cranial asymmetries are skull shape abnormalities caused by external pressure on the developing cranium and are classified by the predominant pattern of deformity. Plagiocephaly presents as unilateral flattening with consequent asymmetry, brachycephaly as occipital flattening with increased cranial width relative to length, and dolichocephaly as the opposite pattern, with a narrow, elongated skull.¹ Plagiocephaly is the most frequent presentation and may be synostotic or deformational.² The synostotic form results from premature fusion of one or more cranial sutures and requires surgical correction, whereas the deformational form results from extrinsic moulding forces and can usually be corrected through positioning measures, physiotherapy or, in moderate-to-severe and refractory cases, a cranial orthosis, or helmet.³ In contrast to the rarity of craniosynostosis, which affects approximately 1 in 2500 newborns, deformational plagiocephaly (DP) is common, affecting between 5% and 48% of children during the first year of life.⁴ Documented prevalence estimates evolved from approximately 1 in 300 newborns in 1974 to 1 in 60 by 1994.⁵ Since the late 1990s, the prevalence of these deformities has risen as a result of sudden infant death syndrome prevention campaigns promoted by the American Academy of Pediatrics: supine sleep positioning

increases the pressure exerted on the occipital region and favours deformational plagiocephaly.² Consistent with this trend, a 2013 Canadian cohort reported plagiocephaly in 46.6% of infants aged 7–12 weeks, 78.3% of whom had mild disease.⁵ These asymmetries are frequently associated with congenital muscular torticollis (CMT), which restricts active head rotation and perpetuates a preferential resting position; they are also more common among preterm infants and in multiple pregnancies.⁶ A systematic review and meta-analysis of 19 studies (14,808 participants) confirmed consistent associations between DP and several non-obstetric factors, while notably finding no consistent association with maternal age, mechanical ventilation, or tummy time.⁷ Closer to our own setting, a Portuguese cohort of 6565 infants found congenital torticollis to have an incidence of 1.5% (95% CI 1.3–1.8%), with plagiocephaly present in 40.7% of affected infants.⁸ Early management is important because untreated deformities have been associated with persistent craniofacial asymmetry, temporomandibular dysfunction, visual disturbances, delayed psychomotor development and psychoemotional impact.⁹

These developmental concerns are supported by a large primary care cohort of 77,108 children, in which plagiocephaly was independently associated with increased odds of a developmental

delay diagnosis (adjusted OR 1.50). Longitudinal follow-up of children with positional plagiocephaly or brachycephaly (n=220) into school age found that cognitive, motor and language differences compared with controls persisted mainly in those with moderate-to-severe deformity, with milder cases showing no significant difference by school age.^{10,11} These children therefore warrant prompt characterisation of the deformity and follow-up until correction is achieved. Cranial orthosis therapy is reserved for moderate-to-severe deformational plagiocephaly persisting after repositioning and physiotherapy, or for infants presenting at an older age, in whom spontaneous correction is less likely.³ Outcomes depend largely on the age at initiation: infants treated earlier, and those with more severe initial deformity, achieve greater correction of cranial shape.^{12,13} In the largest published series, complete correction was obtained in 94.4% of infants treated with a helmet as first-line therapy and in 96.1% of those helmeted after conservative therapy had failed, with poor compliance and older age identified as the main risk factors for failure.¹⁴ Overall, however, the evidence derives mostly from non-randomised studies, and the criteria for quantifying the deformity and defining the optimal treatment window remain unstandardised.¹⁵ A synthesis of systematic reviews and national guidelines found manual therapy more effective than repositioning alone (moderate-to-high quality evidence) but inconclusive when compared with helmet therapy (low-quality evidence), underscoring the heterogeneity of methodologies and outcome measures across the field.¹⁶ Other conservative modalities, such as osteopathic manipulation, have also been proposed, though the supporting evidence remains methodologically weak: a small uncontrolled pilot study without a comparison group reported improvement after treatment, a design that cannot distinguish a true treatment effect from the natural course of the deformity, limiting the validity of its conclusions.¹⁷ This study aimed to characterise a cohort of children with deformational cranial asymmetries assessed at a tertiary referral centre, describing their clinical profile, therapeutic approach and craniometric outcomes under a stepped conservative management protocol, including the subgroup requiring cranial orthosis therapy.

Materials and methods

Study design and population - We conducted a retrospective study of children assessed at the paediatric rehabilitation outpatient clinic of a tertiary referral centre during 2024 with a deformational cranial asymmetry diagnosed within the first year of life. Patients with confirmed or suspected craniosynostosis were excluded. Data were collected from clinical records and included sex, mode of delivery, multiple pregnancy, gestational age, age at diagnosis, age at last assessment, associated torticollis, therapeutic approach (postural repositioning, physiotherapy or cranial orthosis) and cranial measurements at initial assessment and at follow-up.

Treatment approach - No standardised treatment was prospectively applied. The therapeutic approach for each patient reflected clinical judgement at the discretion of the treating physician, informed by the severity and evolution of the deformity, the presence of associated torticollis, and the infant's age. Postural repositioning counselling was provided to all families at diagnosis, typically including instructions on alternating body position during sleep and supervised prone time. Physiotherapy was added when improvement was considered insufficient on clinical reassessment, when torticollis was present, or when the initial deformity was considered more severe, and cranial orthosis was considered in infants with persistent moderate-to-severe

deformity despite conservative measures, or later presentation. Because these decisions were not governed by pre-specified criteria, the distinction between treatment groups in this cohort reflects observed clinical practice rather than a controlled comparison of interventions.

Torticollis - Torticollis was defined clinically, as a sustained preferential head position with limitation of active cervical rotation on physical examination. No complementary tests were performed to confirm sternocleidomastoid involvement. This variable therefore reflects a clinical diagnosis of postural torticollis and does not distinguish congenital muscular torticollis from positional preference.

Cranial measurements - All measurements were obtained with a handheld craniometer at the paediatric rehabilitation outpatient clinic and were performed throughout the study period by the same observer, eliminating inter-observer variability. Caliper-based craniometry has demonstrated excellent intra- and inter-rater reliability for cranial length, width and diagonal measurements (ICC >0.9), and diagnostic agreement with three-dimensional scanning comparable to gold-standard methods ($\kappa=0.8-1.0$; no significant differences in cephalic index or cranial asymmetry values).^{18,19}

The plagiocephaly index (PI) was defined as the absolute difference between the two cranial diagonals in millimetres, and used as the outcome measure in plagiocephaly. Initial deformity was classified as mild (PI <5 mm), moderate (PI 5–10 mm) or severe (PI >10 mm). The cephalic index (CI) was defined as the ratio between maximum cranial width and maximum cranial length, expressed as a percentage, and used as the outcome measure in brachycephaly and dolichocephaly. Because the direction of expected change is opposite in these two diagnoses, CI outcomes were analysed separately rather than pooled.

Outcome definition - Treatment efficacy was defined as complete resolution, i.e. final PI <5 mm. Since patients presenting with an initial PI <5 mm already met this criterion at baseline, a sensitivity analysis restricted to patients with an initial PI ≥5 mm was performed.

Statistical analysis - Analyses were performed using IBM SPSS Statistics 29.0.2.0. Categorical variables are presented as absolute and relative frequencies, and continuous variables as median and interquartile range (IQR), given the sample size and non-normal distribution. Paired measurements were compared using the Wilcoxon signed-rank test, with effect size reported as $r = Z/\sqrt{N}$. Associations between categorical variables were assessed using Fisher's exact test, continuous variables were compared between independent groups using the Mann-Whitney U test, and correlations were assessed using Spearman's coefficient. Ninety-five percent confidence intervals for proportions were calculated using the Wilson method. A p value <0.05 was considered statistically significant.

Ethics - The study was approved by the institutional ethics committee.

Results

Sample characterisation - Forty-six patients were included (Table 1), 26 (56.5%) male, with a median gestational age of 38 weeks (range 30–41). Fourteen (30.4%) were born preterm and 6 (13.0%) resulted from multiple pregnancies. Delivery was eutocic in 24 (52.2%), by caesarean section in 16 (34.8%) and instrumental in 6 (13.0%). Diagnoses were plagiocephaly in 27 (58.7%), brachycephaly in 16 (34.8%) and dolichocephaly in 3 (6.5%). Torticollis was present in 37 (80.4%), left-sided in 25 (67.6%) of these cases.

Table 1 Sample characterisation, treatment, cranial measurements and statistical associations (N = 46)

Variable	n (%) or median [IQR]	Test statistic	p value
Sex, male	26 (56.5)	—	—
Gestational age, weeks	38 [30–41] ^a	—	—
Preterm (<37 weeks)	14 (30.4)	—	—
Mode of delivery			
Eutocic	24 (52.2)	—	—
Caesarean section	16 (34.8)	—	—
Instrumental	6 (13.0)	—	—
Multiple pregnancy	6 (13.0)	—	—
Diagnosis			
Plagiocephaly	27 (58.7)	—	—
Brachycephaly	16 (34.8)	—	—
Dolichocephaly	3 (6.5)	—	—
Associated torticollis	37 (80.4)	—	—
Age at diagnosis, months	2.5 [1.0–4.0]	—	—
Age at last assessment, months	10.5 [7.0–15.2]	—	—
Follow-up duration, months	8.0 [5.0–13.2]	—	—
Treatment received			
Repositioning only	21 (45.7)	—	—
Repositioning + physiotherapy	21 (45.7)	—	—
Cranial orthosis	4 (8.7)	—	—
Initial PI severity (n = 39)			
Mild (<5 mm)	11 (28.2)	—	—
Moderate (5–10 mm)	21 (53.8)	—	—
Severe (>10 mm)	7 (17.9)	—	—
PI, initial (n = 31), mm	6.0 [4.0–10.0]	—	—
PI, final (n = 31), mm	4.0 [1.0–7.0]	Z = 2.08 ^b	0.037 ^b
Complete resolution, PI <5 mm (n = 31)	17 (54.8); 95% CI 37.8–70.8	—	—
Complete resolution, baseline PI ≥5 mm (n = 22)	11 (50.0); 95% CI 30.7–69.3	—	—
CI, initial — brachycephaly (n = 14), %	89.8 [86.2–90.0]	—	—
CI, final — brachycephaly (n = 14), %	86.5 [83.6–89.7]	Z = 1.78 ^b	0.075 ^b
Associations and correlations			
Initial PI severity vs. absolute PI reduction	—	rho = −0.44 ^c	0.014 ^c
Complete resolution vs. age at diagnosis, months	—	U = 142.0 ^e	0.36 ^e
Resolved (n = 17)	3.0 [2.0–4.0]	—	—
Not resolved (n = 14)	2.0 [1.0–4.0]	—	—
Complete resolution vs. torticollis	—	— ^d	0.66 ^d
Torticollis present (n = 25)	13 (52.0%) resolved	—	—
Torticollis absent (n = 6)	4 (66.7%) resolved	—	—
Complete resolution vs. prematurity	—	— ^d	1.00 ^d
Preterm (n = 10)	6 (60.0%) resolved	—	—
Term (n = 21)	11 (52.4%) resolved	—	—
Complete resolution vs. sex	—	— ^d	0.46 ^d
Male (n = 19)	9 (47.4%) resolved	—	—
Female (n = 12)	8 (66.7%) resolved	—	—
Age at diagnosis vs. paired PI data, months	—	U = 273.5 ^e	0.33 ^e
With paired PI data (n = 31)	3.0 [1.5–4.0]	—	—
Without paired PI data (n = 15)	2.0 [1.0–3.5]	—	—
Initial PI vs. paired PI data, mm	—	U = 95.0 ^e	0.32 ^e
With paired PI data (n = 31)	6.0 [4.0–10.0]	—	—
Without paired PI data (n = 8)	8.5 [5.0–14.2]	—	—

PI, plagiocephaly index (diagonal difference); CI, cephalic index; IQR, interquartile range; 95% CI, 95% confidence interval; —, not applicable / not calculated.

^a Median [range]. ^b Wilcoxon signed-rank test for paired samples. ^c Spearman's rank correlation coefficient (rho), used both as the correlation estimate and as the test statistic. ^d Fisher's exact test, which does not produce a test statistic. ^e Mann-Whitney U test, used to compare the distribution of a continuous variable between two independent groups. Proportions presented with 95% confidence intervals calculated by the Wilson method. Severity thresholds: mild <5 mm, moderate 5–10 mm, severe >10 mm.

The median age at diagnosis was 2.5 months (IQR 1.0–4.0; range 0–9) and the median age at the last assessment was 10.5 months (IQR 7.0–15.2; range 5–25), corresponding to a median follow-up of 8.0 months (IQR 5.0–13.2).

Treatment - All patients received postural repositioning as first-line management. This was sufficient in 21 (45.7%); the remaining patients required physiotherapy in 21 (45.7%) or, in the most refractory cases, a cranial orthosis in 4 (8.7%). Physiotherapy preceded orthosis use in three of these four patients.

Cranial measurements and outcome - At initial assessment, the PI was available in 39 patients and was classified as mild in 11 (28.2%), moderate in 21 (53.8%) and severe in 7 (17.9%).

Paired PI measurements were available in 31 patients (67.4% of the sample). The PI decreased significantly, from a median of 6.0 mm (IQR 4.0–10.0) to 4.0 mm (IQR 1.0–7.0) (Wilcoxon signed-rank test, $p=0.037$; $r=0.37$), a median change of -2.0 mm (95% CI -4.0 to -1.0). Complete resolution (PI <5 mm) was achieved in 17 patients (54.8%; 95% CI 37.8–70.8%). As nine of these patients already presented with a PI <5 mm at baseline, a sensitivity analysis restricted to patients with an initial PI ≥ 5 mm yielded complete resolution in 11 of 22 patients (50.0%; 95% CI 30.7–69.3%). A greater initial deformity was associated with a greater absolute reduction in PI (Spearman's $\rho = -0.44$; $p=0.014$), but with a lower rate of complete resolution: 6 of 9 (66.7%) in mild, 10 of 18 (55.6%) in moderate and 1 of 4 (25.0%) in severe deformities. Complete resolution was not significantly associated with age at diagnosis, torticollis, prematurity or sex (Table 1). Paired CI measurements were available in 31 patients. Among the 14 patients with brachycephaly, the CI decreased from a median of 89.8% (IQR 86.2–90.0) to 86.5% (IQR 83.6–89.7), without reaching statistical significance ($p=0.075$; $r=0.48$). In the three patients with dolichocephaly, the CI increased from 69.7%, 71.4% and 72.0% to 76.0%, 80.0% and 80.0%, respectively. In the 14 patients with plagiocephaly, the CI remained within the normal range throughout follow-up and was therefore not used as an outcome measure. Only four patients were treated with a cranial orthosis, and paired measurements were available in a single case; no efficacy estimate could therefore be derived for this modality.

Missing data - Paired PI measurements were unavailable in 15 patients (32.6%), mostly among those with plagiocephaly (13/27). Patients with and without complete paired data did not differ significantly in age at diagnosis or initial PI (Table 1).

Discussion

This study characterises a cohort of 46 children with deformational cranial asymmetries assessed at a tertiary referral centre over one year, and describes their craniometric evolution under a stepped conservative management protocol.

Early diagnosis and referral - The median age at diagnosis was 2.5 months (IQR 1.0–4.0), earlier than reported in most published series. A standardised physiotherapy protocol combining repositioning exercises and manual techniques showed the most consistent improvement in infants treated between 5 and 8 months of age, with greater variability in outcomes among younger infants and better-than-average improvement in those starting after 8 months, reinforcing that the timing of intervention interacts with treatment modality.²⁰ This matters because the potential for cranial remodelling is greatest during the period of fastest skull growth: infants treated earlier achieve greater correction, while treatment started after 11 months yields substantially poorer outcomes.^{12,13} The early referral observed here

likely reflects both the structure of the referral network and greater awareness of cranial deformities among primary care paediatricians.

Low requirement for cranial orthosis - Only 4 (8.7%) of our patients required a cranial orthosis, below the 15.8% crossover rate to helmet therapy reported by Steinberg *et al.* in a series of 4378 infants.¹⁴ The two cohorts are not directly comparable, differing in referral pathways, measurement methods and thresholds for escalation, but this finding is consistent with synthesised evidence favouring manual therapy and repositioning over helmet therapy as first-line approaches, given the low-certainty evidence supporting helmet superiority and its associated burden [16]. This is relevant given the cost of cranial orthoses and their reported burden of side effects: in the only randomised controlled trial available, all parents in the helmet group reported adverse effects, and no benefit was demonstrated over the natural course of the deformity in infants aged 5–6 months.¹⁵ Our data cannot establish causality, but they support the value of accessible early referral pathways.

Severity and correction - Greater initial deformity was associated with a greater absolute reduction in PI ($\rho = -0.44$; $p=0.014$), while the probability of complete resolution fell as severity increased: 6 of 9 (66.7%) in mild, 10 of 18 (55.6%) in moderate and 1 of 4 (25.0%) in severe deformities. This apparent paradox is consistent with the literature.^{13,14} In practice, this means that severe deformities tend to improve substantially under conservative management, even though families should be counselled that complete normalisation is less likely.

Clinical implications - These findings offer a descriptive picture of how children with deformational cranial asymmetries evolved under a stepped conservative protocol at a single tertiary centre, rather than a basis for treatment recommendations. Most infants improved without requiring cranial orthosis, and the inverse relationship between initial severity and probability of complete resolution was consistent with the natural trajectory described in the literature, independently of the specific intervention received. Whether this pattern reflects the protocol applied, the natural course of the deformity, or both cannot be determined from a retrospective, uncontrolled design, and spontaneous resolution with cranial growth remains the most likely explanation for a substantial part of the improvement observed.

Torticollis - Torticollis was present in 37 (80.4%) of our cohort, a higher proportion than the 40.7% co-occurrence of plagiocephaly reported in a Portuguese cohort of infants with torticollis, though direct comparison is limited by differing inclusion criteria: our cohort selected for cranial asymmetry rather than torticollis as the index diagnosis.⁸ This most likely reflects the referral profile of a tertiary rehabilitation clinic, where children with cervical postural restriction are preferentially referred, combined with a clinical definition that does not distinguish congenital muscular torticollis from positional preference. The association between cervical postural asymmetry and cranial deformity is nonetheless well established,⁵ and the high proportion observed reinforces the importance of systematic cervical examination in infants presenting with skull deformity.

Prematurity and perinatal profile - Preterm infants accounted for 14 (30.4%) of our cohort, a proportion above the prevalence of preterm birth in the general population. This finding is in line with a meta-analysis identifying prematurity among the non-obstetric factors consistently associated with deformational plagiocephaly.⁷ Prematurity is indeed a recognised risk factor,⁶ plausibly acting through greater skull malleability and prolonged immobility during neonatal intensive care, together with delayed acquisition of cervical motor control. This proportion is expected in a centre whose referral base includes a

neonatal intensive care unit, and it supports systematic surveillance of head shape during neonatal follow-up, when repositioning is most effective. Instrumental delivery (6, 13.0%) and multiple pregnancy (6, 13.0%) were also frequent, both recognised risk factors acting through intrauterine constraint and birth-related mechanical forces.⁶

Outcome definition - We used the same resolution threshold as Steinberg *et al.* (PI <5 mm),¹⁴ allowing direct comparison. This threshold, however, coincides with the upper limit of mild deformity, so that nine patients already met the criterion at baseline. We therefore consider the sensitivity analysis restricted to an initial PI ≥5 mm — 11 of 22 patients (50.0%; 95% CI 30.7–69.3%) — the more valid estimate.

Limitations - Several limitations must be acknowledged. First, and most importantly, the absence of a control group means the observed improvement cannot be attributed to the intervention. Deformational asymmetries improve spontaneously with cranial growth, and randomised evidence suggests a substantial proportion normalise without treatment.¹⁵ Our findings therefore describe the clinical course under a stepped conservative protocol rather than demonstrate efficacy. Second, the retrospective design left 15 (32.6%) of patients without paired measurements, although these did not differ significantly from the remainder in age at diagnosis or initial deformity. Third, the timing of the final assessment was not standardised (5–25 months) and the sample size limits statistical power, so that “resolution” reflects heterogeneous points along the natural trajectory and the absence of significant associations should not be read as evidence of absence. Fourth, the severity thresholds applied were not derived from a validated classification system. Multiple indices exist to grade severity, such as the cephalic index, cranial vault asymmetry, the cranial vault asymmetry index (CVAI), and the oblique cranial length ratio, each with distinct normal/mild/moderate/severe cut-offs, and none universally adopted. This precludes direct comparison of our classification with series using alternative indices, particularly the CVAI.⁵ Finally, the small orthosis subgroup (n=4) precluded any comparative analysis. Despite these limitations, this study has notable strengths. Measurements were performed by a single observer throughout the study period, eliminating inter-observer variability, a methodological advantage supported by evidence of excellent reliability for caliper-based craniometry.^{18,19} The cohort was drawn consecutively from a tertiary referral centre, minimising selection bias within the population referred for assessment, and patients were managed under a clearly defined, stepped conservative protocol, allowing a transparent description of the clinical pathway from diagnosis to resolution.

Conclusion

This study suggests that most children with deformational cranial asymmetries referred to a tertiary rehabilitation centre can be managed successfully with conservative measures, namely postural repositioning and physiotherapy, with cranial orthosis reserved for a minority of more refractory cases. Improvement in craniometric measurements was consistently observed over follow-up, although complete normalisation was less likely in infants presenting with more severe deformity at baseline — a distinction that should inform how families are counselled about realistic expectations. Because this was a retrospective study without a control group, the observed improvement cannot be firmly attributed to the treatment provided rather than to the natural course of the condition. These findings nonetheless reinforce the value of early identification and accessible referral pathways, and underline the need for prospective, controlled

studies using standardised assessment timepoints and validated severity indices to disentangle treatment effect from natural evolution.

Acknowledgments

None.

Conflicts of interest

The authors declares that there are no conflicts of interest.

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