Original Article

Active Counterpositioning or Orthotic Device to Treat Positional Plagiocephaly?

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Active counterpositioning and orthotic helmets are the two main nonsurgical management options for positional plagiocephaly. The purpose of this study was to compare these two management regimens. We included a random sample of infants referred between January 1, 1998 and October 31, 1999 to Middlemore Hospital and Auckland Surgical Center, for management of positional plagiocephaly. Two-dimensional head tracings were taken for each infant, every 3 to 12 months. From these tracings, we obtained Cranial Index and Cranial Vault Asymmetry Index. Seventy-nine infants were assessed during an average of 48.2 weeks. Five infants had normal head tracings, and were therefore excluded from the study. Of the 74 infants included in this study, 45 were managed with active counterpositioning, and 29 with orthotic helmets. Average management time for active counterpositioning was 63.7 weeks, and 21.9 weeks for orthotic helmet treatment. For infants managed with active counterpositioning, the average change in Cranial Vault Asymmetry Index was 1.9%. In the orthotic group, average change in Cranial Vault Asymmetry Index was 1.8%. Orthotic helmets have an outcome comparable to that of active counterpositioning, although the management period is approximately three times shorter. Active counterpositioning generally had a slightly better outcome than orthotic management after the management period.

Key Words: Active counterpositioning, orthotic device, positional plagiocephaly, Cranial Index, Cranial Vault Asymmetry Index

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Referrals of plagiocephaly to specialist plastic and neurosurgery clinics have increased by as much as 600% in the last 8 years.[1,2] This radical escalation is thought to have followed the implementation of the "Back to Sleep" Campaign initiated by the American Academy of Pediatrics in 1992.[3] Controversy still exists over how to prevent positional plagiocephaly from developing, and its most appropriate management regimens.[3] Infant healthcare professionals tell many parents of infants with positional plagiocephaly that any cranial dysmorphism will dissipate over time. This may occasionally happen, but for the majority of infants there will be permanent residual deformation.[4,5] This may be mild, or camouflaged by hair.

Plagiocephaly literally means "skewed head." One of the most common causes of this condition is through positional deformation. Positional plagiocephaly is caused by an unbalanced external force applied during a long period to the skull of a fetus or infant. This force may be applied in utero or in the neonatal period, such as by sleeping infants on the same part of his or her head every night.[4,6] Lying an infant on the same part of his or her head will allow that part of the skull to become flat under the force of gravity. Unchecked, the asymmetry will increase over time. Unless prevented from doing so, the infant will tend to sleep on the flat spot, in the same way a flattened ball will come to rest on the flat part. When an infant's head becomes flat, the head will automatically come to rest on the flat region. Typically, a plagiocephalic infant will develop a "wind swept" appearance, flat posterolaterally and anterolaterally, with contralateral bossing. The ear ipsilateral to the occipital flattened area may be anterior to the contralateral ear. This results in a parallelogram-shaped cranium that has a tendency to become brachycephalic. These features are summarized in Table 1.

Torticollis has been associated with 64% to 84% of infants born with a normal head shape who develop positional plagiocephaly.[3,4,7,8] The sternocleidomastoid muscle may be tightened congenitally,

Table 1. Key Features of Positional Plagiocephaly

History	*—Noticed skull asymmetry either at birth, or within first few months of life*
	—Early or abnormal prenatal descent into maternal pelvis
	—Sleeps supine
	—Sleeps in car seat for several hours per week
Investigations	—Parallelogram cranium when viewed from above
	—Cranium flat posteriorly, usually unilaterally
	—Ipsilateral ear anterior and inferior
	—Ipsilateral frontal bossing
	—Contralateral frontal flattening
	—Contralateral occipital bossing
	—Torticollis
Examinations	—Plain film radiograph—lambdoid sutures patent
	—CT (if plain film is unclear)—all sutures patent
	—Head tracing and photographs
Management	—Counterpositioning—Follow-up 6 weeks
	—Moulding Helmet—Follow-up 3 weeks
	—Physiotherapy

or perhaps secondary to plagiocephaly itself.[2] Consistently lying on one side of the head may cause slight shortening or tightening of the sternocleidomastoid muscle. Other abnormalities also associated with positional plagiocephaly include congenital hip dislocation, vertebral scoliosis, sternocleidomastoid muscle tumors, and prominent ears.[6] Positional plagiocephaly is more likely to develop in preterm infants.[2]

Materials and Methods

A random sample of infants referred between January 1, 1998 and October 31, 1999 to a specialist craniofacial service, for management of positional plagiocephaly, were included in this study. Standard plain film skull radiographs were examined to rule out lambdoid synostosis, particularly when there were phenotypic traits of both positional plagiocephaly and lambdoid synostosis. Usually the sutures were obviously patent. Sometimes, however, a suture appeared "sticky." A sclerotic margin adjacent to the suture may have been noted. This is not a valid diagnostic sign for synostosis, because the sclerosis may be secondary to deformational forces.[8] No standard tool for quantitative assessment of progress has been described in the literature. It is desirable to consistently measure the progress of each infant in a reproducible and comprehensive manner. Some authors have recommended computed tomography analysis.[9] Cost concerns aside, serial application of this technique would expose infants to high doses of radiation and risks of complications from general anesthetic.

Various anthropometric analyzes have been described in the literature.[3,5] Many of these require careful measurement of the infant's cranium with callipers. Usually an infant is averse to having his or her head measured, and will not remain still during measurements. The author would question the accuracy and safety of these fine measurements. We devised a simple method of anthropometric analysis, using an artist's flexicurve—a long, flexible rubber tube filled with lead and silicon–to obtain a circumferential head tracing. The curve was placed firmly around the infant's head, without it losing its shape when removed from the head. In this way a two-dimensional representation of the shape of an infant's head could be traced on paper. We marked the position of the ears, inion, and nasion on the tracing. Head tracings were reproducible to within 2 mm. From these head tracings, we were able to obtain a cranial index (CI) and cranial vault asymmetry index (CVAI) (Fig 1). CI is an index of the cranial width divided by cranial length.

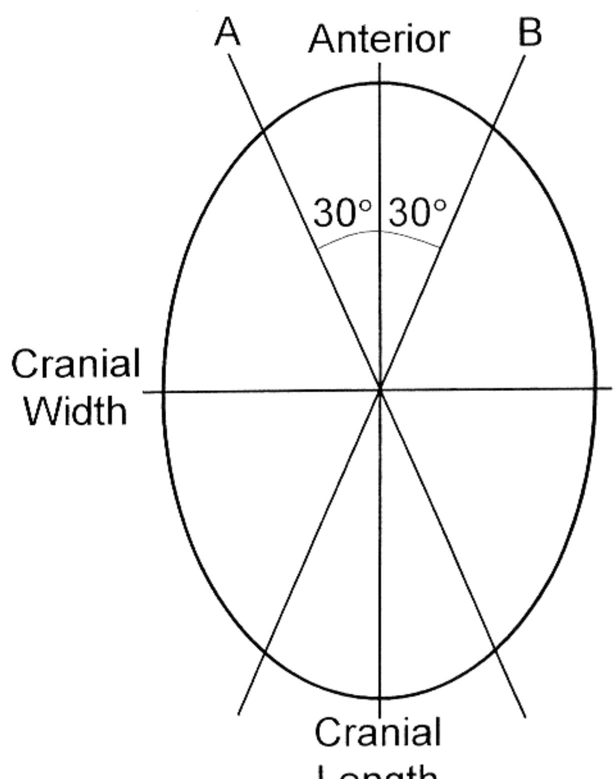

Fig 1 Head tracings yielded a cranial index and cranial vault asymmetry index.

$$\text{Cranial Vault Asymmetry Index} = \frac{\text{diagonal A} - \text{diagonal B}}{\text{diagonal A}} \times 100$$

CI represents the width of the head as a percent of the length of the head. Normal CI range is from 75% to 85%. is an index of cranial asymmetry. It is calculated from the difference in length between the two diagonal lines (A and B, where A < B) drawn 30° *from the anterior–posterior pole,* divided by the shorter of the two diagonal lines.

$$\text{Cranial Index} = \frac{\text{cranial length}}{\text{cranial width}} \times 100$$

CVAI represents the asymmetry of the cranial vault. A perfectly symmetrical head will obtain a CVAI score of 0%. A head may be said to be significantly asymmetrical if the CVAI is >3.5%. An index of cranial vault asymmetry has been used rather than the actual difference between the two diagonal lengths, because of variation in infant head size. The difference between the two diagonal measurements in an infant with a small head may be 4 mm. This infant could have CVAI larger than an infant with asymmetry of 6 mm who has a larger head. Experimental errors were calculated for the head tracings. The measurements could be reproduced to within 2 mm. Allowing for scale error of ±2 mm, absolute error in each measurement was ±4 mm. Using addition in quadrature and the index equations above, the relative error in CI was calculated to be ±4%, and the relative error in CVAI ±5%. We believed that this method of measurement, in the clinical setting, was useful as an approximate guide to the efficacy of therapeutic interventions. However, because of the general inaccuracies involved in calculating indices from head tracings, we are currently involved in developing a measurement technique based on digital photography and immediate computer-based analysis of the image.

All cases of craniosynostosis were excluded on examination of skull radiographs for each infant. Perinatal and neonatal histories were obtained to ascertain any positioning that may have precipitated the development of positional plagiocephaly. Sleeping position used, hours spent in a car seat per week, and history of torticollis and other abnormalities were noted. Cervical spine radiographs were examined to rule out vertebral deformities in infants with torticollis. Head tracings for 79 infants were evaluated to obtain CI and CVAI. The infants were divided into two groups: those managed with active counterpositioning (ACP), and those managed with an orthotic helmet. For further analysis, these groups were then categorized into two subgroups: infants who were brachycephalic on presentation of plagiocephaly, and infants who were not brachycephalic. Brachycephaly was defined arbitrarily as CI ≥ 85% (i.e., a broad head). The primary reason for this analysis was because orthotic helmets can be difficult to fit a markedly brachycephalic head because of the absence of an occiput around which the helmet can mould. This can lead to the helmet slipping off the head, or moving to a different position. We also looked at the effects of age on treatment efficacy. The magnitude of the cranial dysmorphism, degree of midoccipital flattening, and the preference of the consulting specialist determined which infants were managed with an orthotic helmet. Some patients were initially managed by ACP, yet failed to show improvement. This necessitated orthotic management. Data from such cases were included only during orthotic management.

Caregivers of infants managed with ACP were told to endeavor to never allow their infant to sleep on the flat spot of his or her head. They should rearrange the room, mobiles above the infant's bed, the position of the bed in relationship to the door and window, any toys or brightly colored objects near the infant's bed, which side of the car the infant car seat is placed, and anything else that would allow the infant to rest on the flat spot. Nursing and carrying positions may also require alteration. Caregivers of infants with torticollis were encouraged to engage the infant in active neck-stretching exercises such as by playing games that involved head turning. Once the infant started changing position during sleep, then head tracings were taken less frequently.

Results

Management Regimen

Seventy-nine infants were assessed during an average of 48.2 weeks. Five infants had normal initial and postmanagement head tracings, and were therefore excluded from the study. Head tracings were obtained every 3 to 12 months, depending on the severity of the asymmetry and age of the infant. Average age of first cranial measurements was 37.5 weeks. Our results are summarized in Table 2.

Of the 74 infants included in this study, 45 were managed with ACP, and 29 received helmet treatment. The average initial measurement age was 38.1 and 36.6 weeks for ACP and orthotic helmets, respectively. Average management time for ACP was 63.7

Table 2. Comparison Between ACP and Orthotic Helmets

	All Subjects (n = 74)	
Treatment Variable	*ACP (n = 45)*	*Orthotic Helmet (n = 29)*
Average age (weeks)	38.1	36.6
Average duration (weeks)	63.7	21.9
Initial CVAI (%)	7.3	8.0
Ending CVAI (%)	5.4	6.2
Change in CVAI (%)	−1.9	−1.8
Initial CI (%)	88.2	89.6
Ending CI (%)	86.2	87.8
Change in CI (%)	−2.0	−1.8

CVAI = cranial vault asymmetry index; CI = cranial index; ACP = active counterpositioning.

weeks, and 21.9 weeks for orthotic helmet treatment. Therefore, cases managed with ACP were treated, on average, for approximately three times longer than cases managed with orthotic helmets. For infants managed with ACP, the average initial CVAI was 7.3% (range: 0–17.6). Average final CVAI was 5.4% (range: 0–10.81). In the orthotic helmet group, the average initial CVAI was 8.0% (range: 1.39–14.4). Average final CVAI was 6.2% (range: 0–15.67).

Initial Head Shape

We then divided the subjects into two groups: those who were brachycephalic at the initial measurement and those who were not. In the brachycephalic group, 29 infants were managed with ACP, and 22 with orthotic helmets. In the group that was not brachycephalic, 16 were managed with ACP, and 7 with orthotic helmets. In the brachycephalic group, those managed with ACP showed an average improvement in CVAI from 8.5% to 5.8%. Those managed with orthotic helmets in the brachycephalic group showed an average improvement in CVAI from 8.2% to 6.4%. In the group that was not initially brachycephalic, those managed with ACP showed an average improvement in CVAI from 5.2% to 4.6%, and those managed with orthotic helmets from 7.4% to 4.6%. These results are summarized in Table 3.

Age

We divided the subjects into two groups: those who started a management regimen before reaching 36 weeks of age, and those who started a management regimen after 36 weeks. For the group that started management before 36 weeks, 23 were managed with ACP, and 17 with orthotic helmets. The ACP subjects showed an average improvement in CVAI from 7.9% to 5.5%, and the orthotic subjects showed an average improvement in CVAI from 8.3% to 6.8%. In the group that started management after 36 weeks, 22 were managed with ACP, and 12 with orthotic helmets. The ACP subjects showed an average improvement in CVAI from 6.8% to 5.3%, and the orthotic subjects showed an average improvement in CVAI from 7.5% to 5.3%. These results are summarized in Table 4.

Discussion

Referrals of infants presenting with positional plagiocephaly to Middlemore Hospital have increased by approximately 300% since 1992. This rise is concomitant with the recommendations of the American Academy of Pediatrics to sleep healthy neonates in a supine position. Many family doctors and infant healthcare nurses are not aware of how to

Table 3. Comparison Between Brachycephalic and Nonbrachycephalic Head Shapes

	Brachycephalic (n = 51)		*Nonbrachycephalic (n = 23)*	
Treatment Variable	*ACP (n = 29)*	*Orthotic Helmet (n = 22)*	*ACP (n = 16)*	*Orthotic Helmet (n = 7)*
Average age (weeks)	36.0	37.7	42.0	33.1
Average duration (weeks)	53.9	22.5	81.6	19.9
Initial CVAI (%)	8.5	8.2	5.2	7.4
Ending CVAI (%)	5.8	6.4	4.6	5.6
Change in CVAI (%)	−2.7	−1.8	−0.6	−1.8
Initial CI (%)	92.7	93.3	80.1	78.0
Ending CI (%)	88.6	90.7	81.7	78.8
Change in CI (%)	−4.1	−2.6	+1.7	+0.8

CVAI = cranial vault asymmetry index; CI = cranial index; ACP = active counterpositioning.

Table 4. Comparison Between Age Groups

	Management Initiated Before 36 weeks of Age (n = 40)		*Management Initiated After 36 Weeks of Age (n = 34)*	
Treatment Variable	*ACP (n = 23)*	*Orthotic Helmet (n = 17)*	*ACP (n = 22)*	*Orthotic Helmet (n = 12)*
Average age (weeks)	26.7	29.9	50.1	46.1
Average duration (weeks)	61.8	24.5	65.7	18.2
Initial CVAI (%)	7.9	8.3	6.8	7.5
Ending CVAI (%)	5.5	6.8	5.3	5.3
Change in CVAI (%)	−2.4	−1.5	−1.5	−2.2
Initial CI (%)	89.5	89.2	87.0	90.1
Ending CI (%)	86.6	88.0	85.7	87.5
Change in CI (%)	−2.9	−1.2	−1.3	−2.6

CVAI = cranial vault asymmetry index; CI = cranial index; ACP = active counterpositioning.

prevent positional plagiocephaly from developing, how to manage it, or know how it differs from craniosynostosis.[10,11] A large proportion of cases is eventually referred to specialist plastic or neurosurgeons, after the most appropriate management age has passed. This can be a very distressing time for parents. There has been a large increase in the incidence of plagiocephaly in the last few years, without appropriate education at the primary care level. In the literature, incidence of plagiocephaly is often quoted as 1 in 300 live births.[12] Dunn, however, published these data in 1976[13]–well before the rise in popularity of infant supine sleeping recommendations.

Positional plagiocephaly is often associated with torticollis. This usually presents with the infant persistently holding his or her head to one side, with a tendency to maintain asymmetric head tilt and rotation. In most cases, history and physical examination will confirm the suspected diagnosis. Observing the shape of the infant's head and position of the ears from above, the plagiocephalic head is typically flattened posteriorly, with the ipsilateral ear anterior to the contralateral ear. Often there is compensatory flattening and/or bossing in the frontal region of the head. There may be some degree of facial scoliosis. Once plagiocephaly has been diagnosed, and craniosynostosis is ruled out on the basis of clinical examination and skull radiographs, the caregivers of the infant should be advised to manage the plagiocephaly with ACP. The infant would require follow-up tracings every 6 to 12 weeks to ensure that satisfactory progress is being made.

Although the data sets in this study are too small to be statistically significant, they do show certain trends. Orthotic helmets have a reasonable outcome that is comparable to that of ACP, although the management period is approximately three times shorter. Generally, however, because the velocity of brain and hence skull growth decreases after approximately one year of age, orthotic helmets are less efficacious in those infants who present late, or who are older than age 12 months.[14] However, infants who fail to show improvement with conservative management are potential candidates for cranial moulding orthoses. These orthotic devices take advantage of the rapid growth of the infant skull in the first year of life. Eighty-five percent of postnatal skull growth occurs in this period.[15] During this time, the skull has the greatest potential for remodeling, and is most sensitive to the moulding effects of external forces.[14] The helmet should be worn as much as possible, and we recommend 22 to 23 hours a day. Orthotic helmets require much perseverance from both healthcare professionals and the child and family. An orthotic helmet costs approximately $450 (US$180) in New Zealand, and its fitting requires the expertise of a specialized orthotist. Hard-shell orthotic helmets are made from polypropylene. The helmets are custom designed for each infant. A cast is made of the head, and from this a negative mold and then a positive mold are made. The orthotic helmet is then made from the positive mold, and chin and side straps added. In our center, we are still perfecting helmet manufacture techniques. Many of the problems we encountered may have been caused by poorly manufactured and fitted helmets. Some of these problems were as follows:

1. Often the helmet did not fit properly at first, and had to be modified numerous times.
2. The helmets became very hot and sweaty, which occasionally caused heat rash on the infant's skin.

3. Helmets that were too tight caused skin injury over pressure points.
4. Some infants had a reaction to materials used to line the helmets.
5. Older infants often were able to undo chinstraps and remove the helmet.
6. If the infant was markedly brachycephalic, the orthotic helmet may not have sat correctly on his or her head. With no occiput around which the helmet can mold, it could easily slip off the head, or turn around.
7. Many infants did not accept helmets well, and became distressed when wearing one. This happened more so if the infant was freely mobile and older.
8. Some caregivers were embarrassed by the helmet, and preferred that the infant did not wear it when in public, such as when at the supermarket. The helmets attracted attention, much of which was undesired.

Not all cases of plagiocephaly are suitable for orthotic management, especially if the infant is markedly brachycephalic, older than 12 months of age, and mobile. Even some 6- and 8-month-old infants may object to the imposition of a helmet. These factors must be taken into consideration when deciding on a management regimen for positional plagiocephaly.

ACP and orthotic helmets are fairly comparable as effective management regimens for positional plagiocephaly. In our hands, they give similar results, although orthotic devices took considerably less time to do so. To obtain the same result, an infant must be managed approximately two or three times longer with ACP than with orthotic helmets. However, in our experience, ACP generally had a slightly better outcome than orthotic management. This could be attributed, at least in part, to difficulties with helmet manufacture and fitting. It is also possible that caregivers who used ACP were more likely to be determined to persevere with the management of plagiocephaly than parents who were relying on a technological device. Few parents of infants who wore orthotic helmets were able to fully comply with our recommendations for the helmets.

Conclusions

Positional plagiocephaly is a common condition, which has increased in incidence in parallel with the rise in popularity of sleeping infants in a supine position. There are two main nonsurgical management options for positional plagiocephaly: ACP and orthotic helmets. These two treatments have similar efficacies, although orthotic management requires a shorter time. Orthotic helmets are expensive, and may not be necessary for all cases of positional plagiocephaly. This is especially so if the infant is markedly brachycephalic (it is difficult to fit the helmet because of the absence of an occipital bulge), older than 12 months of age (the infant would be required to wear the helmet for a much longer time), and mobile (the infant will try to remove the helmet, and would not spend much time on the flat region anyway). A combination between the two management regimens could be the most effective management for positional plagiocephaly. Prevention, or failing that, early treatment, ensures the best results.

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References

1. McAlistair WH. Invited commentary: Posterior deformational plagiocephaly. Pediatr Radiol 1998;28:727–728
2. Kane AA, Mitchell LE, Craven KP, et al. Observations on a recent increase in plagiocephaly without synostosis. Pediatrics 1996;97:877–885
3. Moss SD. Nonsurgical, nonorthotic treatment of occipital plagiocephaly: What is the natural history of the misshapen neonatal head? J Neurosurg 1997;87:667–670
4. Huang MHS, Gruss JS, Clarren SK, et al. The differential di agnosis of posterior plagiocephaly: True lambdoid synostosis versus positional moulding. Plast Reconstr Surg 1996;98:765–774
5. Ripey CE, Pomatto J, Beals SP, et al. Treatment of positional plagiocephaly with dynamic orthotic cranioplasty. J Craniofac Surg 1994;5:150–159
6. Watson GH. Relation between side of plagiocephaly, dislocation of hip, scoliosis, bat ears, and sternomastoid tumors. Arch Dis Child 197;46:203–210
7. Fernbach SK. Craniosynostosis 1998: concepts and controversies. Pediatr Radiol 1998;28:722–728
8. O'Broin ES, Allcutt D, Earley MJ. Posterior plagiocephaly: Proactive conservative management. B J Plast Surg 1999;52:18–23
9. Abbott AH, Netherway DJ, Moore MH, et al. Computer tomography determined intracranial volume of infants with deformational plagiocephaly: a useful "normal"? J Craniofac Surg 1998;9:493–503
10. Brunteau RJ, Mulliken JB. Frontal plagiocephaly: Synostotic, compensational, or deformational. Plast Reconstr Surg 1992; 89:21–31
11. Ortega R. Unkind cut. Wall Street Journal 1996;February 29:A1–5
12. Rekate HL. Occipital plagiocephaly: a critical review of the literature. J Neurosurg 1998;89:24–30
13. Dunn PM. Congenital postural deformities. Br Med Bull 1976; 32:71–76
14. Kelly KM, Littlefield TR, Pomatto JK, et al. Cranial growth unrestricted during treatment of deformational plagiocephaly. Pediatr Neurosurg 1999;30:193–199.
15. Pollack IF, Losken HW, Fasick P. Diagnosis and management of posterior plagiocephaly. Pediatrics 1997 Feb;99:180–185