Neonatal Cranial Molding and Positioning Changes Related to Respiratory Device Literature Review

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Abnormal cranial molding is a complex, multifaceted deformation commonly seen in premature infants. Wolff's law states that bones remodel according to the forces applied to them, and this is especially true of infant cranial bones[1]. The cranial sutures, joints between the bones, have not become immobile yet and provide more ductility in the skull[1]. Infant bones, specifically preterm infant bones, have an extremely high rate of collagen production which makes them increasingly malleable[1]. Premature infants are also more susceptible for acute respiratory distress and mechanical ventilation to stabilize ventilation and oxygenation[1,2]. During this time continuous positive airway pressure (CPAP) machines are used to provide continuous airflow and stabilize blood gas levels in preterm infants[2]. These machines can apply pressures to certain areas of the cranium, resulting in abnormal cranial molding and poor head growth[2,3]. During this time positioning is commonly used by pediatric physical therapists as an intervention strategy to promote normal development and help with oxygenation; however, increased time spent in any one position can cause deformational pressures to the cranium, possibly resulting in abnormal cranial molding[1-3]. Literature indicates that multiple factors impact oxygenation status and cranial formation in preterm infants. The purpose of this review is to examine the interplay of these factors and their effects on cranial molding, particularly the development of dolichocephaly.

Positioning is a common intervention to improve oxygenation and respiration in patients of all ages. In preterm infants the use of CPAP machines can impact the frequency of positional changes and the variations of positions available. Positioning has further implications for both respiration, motor outcomes, and normal cranial development[4-6]. Studies support prone positioning as superior to supine for improving oxygenation and reducing apneic episodes in preterm infants receiving mechanical ventilation[4-7]. Oxygenation parameters such as SpO2 (oxygen saturation) and FiO2 (friction of inspired oxygen) improve when infants are placed in the prone position[8,9]. In the case of preterm infants on CPAP, even alternating prone and supine for 2-4 hours at a time can provide short-term improvements in oxygenation and help stabilize respiration[8]. There is also a time dependent component to respiration and oxygenation that is associated with positioning, indicating that infants tend to stabilize and increase oxygenation parameters when left in prone for at least 2 hours[8,10]. This suggests that there are benefits in mobility for ventilated infants as the change in positioning can produce short-term improvements in oxygenation, increase ease of nursing care, and aid in procedures such as heel-sticks and suctioning[11]. Extended mechanical ventilation is also strongly associated with abnormalities in head growth and further deformation of the head; however, literature debates the role positioning has when compared to pressures applied to the head by CPAP machines[12,13]. While further research is needed in this area, the overall implication is that prone positioning is beneficial for oxygenation in preterm infants and may reduce the duration of mechanical ventilation, and possibly subsequent risk of cranial deformation.

Premature infants in the neonatal intensive care unit (NICU), especially those of very low birth rate, are at an increased risk developing head and cranial molding deformities. This is due to the increased malleability to the neonate skull, weight of gravity, and often sustained supine positioning[13,14]. If present at 32 to 34 weeks postmenstrual age, dolichocephaly has been linked to adverse motor outcomes and decreased developmental stages following hospital discharge[13]. To decrease the prevalence of dolichocephaly in preterm infants, direct positional change intervention is needed[13]. While supine positioning is recommended to limit the development of dolichocephaly, supine positioning is not ideal for developmental care and secondary conditions, such as respiratory distress[13]. Nuysink et al cites that if infants remain resting in supine, this can be predictive of asymmetric motor performance[15]. When dolichocephaly is present at 32 to 34 weeks postmenstrual age (PMA) or at hospital discharge, the infant is more likely to maintain this head shape deformity at an outpatient follow-up and demonstrate a combination of adverse motor outcomes[13,16]. These adverse motor outcomes are also believed to contribute to early motor delays, asymmetrical motor performance, and result in an increased need for outpatient physical therapy services[1]. It is hypothesized that for successful treatment of dolichocephaly, systematic positional changes are needed to overcome the mechanical forces repetitive positioning places on head shaping of preterm and/or very low birth weight infants[13-16]. While a multitude of studies throughout the literature indicate the correlation between preterm or low birth weight delivery and the development of cranial molding deformities, these studies do not establish nor investigate a regimented positional protocol to prevent and/or treat cranial molding deformities[2,17]. Literature highlights the prevalence and implications of dolichocephaly; however, further research is needed on positional change and positional protocols, to establish the best method for treating and preventing the development of dolichocephaly in the NICU[2,13,18].

Measurement selection can also greatly impact research outcomes and understanding of cranial deformities as well. Head symmetry is commonly measured using head circumference taping, calipers, and anthropometric landmarks[19]. Literature indicates that there are five primary measurements used to define and track head shape progression. These include head circumference, head width, head length, cranial index, and cranial vault asymmetry (CVA)[19]. Cranial Index (CI), which is also commonly referred to as the Cranial Proportional Index or Cephalic Index, is measured by dividing the width of the infant's head by the length, and multiplied by 100 to be reported as a percentage[20]. While values slightly vary throughout the literature, normal ranges are typically defined as 76% to 90%, with brachycephaly being defined as a CI greater than 90% and dolichocephaly as a CI greater than 76%[19-21]. Considering CI represents the ratio of the maximum cranial width to maximum cranial length, it is commonly used for isolated sagittal synostosis (ISS), but is also used to define dolichocephaly and brachycephaly[19,20]. On the other hand, cranial vault asymmetry is the difference between two diagonal measurements (the left or right frontozygomaticus to the opposite eurion)[20,21]. CVA can also be used to determine Cranial Vault Asymmetry Index (CVAI). While CVA is the absolute value of the difference of the cranial diagonals, CVAI is determined by taking the CVA and dividing this value by the longer diagonal and multiplying by 100[19]. Therefore, CVAI is the measurement of the CVA in relationship to the overall size and shape of the head[19]. CVAI is most typically used to measure plagiocephaly, as this value will be symmetric in symmetric brachycephaly and dolichocephaly[20]. In terms of plagiocephaly, a CVAI of 3.5% or less is defined as normal, with 3.5% to 6.25% denoting mild, 6.25% to 8.75% indicating moderate, 8.75% to 11.0% for severe, and any value over 11% being defined as very severe[19,20].

Deformational dolichocephaly is characterized by a long, slender head shape that typically results from extreme head rotation to one side or through increased usage of respiratory devices[2]. This head shape deformity is most commonly observed in premature infants who spend prolonged lengths in the neonatal intensive care unit[20]. Defined as having an cranial index of greater than 76%, observation demonstrates a narrow skull, with a normal increase in width from anterior to posterior[19,20]. Dolichocephaly affects the occiput, temporal, parietal, and frontal bones, and may impact facial structure[20]. Recent literature by Graham et al indicates that asymmetrical brachycephaly can be accurately defined using both CI and CVAI (of greater than 3.5%), but that initial CI was found to be a stronger predictor as to which subjects achieved head shape correction than CVAI[19]. Deformational brachycephaly is described as occipital flattening and as mentioned above, can be defined by an increased CI (wide head) or an increased CVAI[22,23]. Deformational brachycephaly is often observed in conjunction with plagiocephaly[22,23]. Plagiocephaly is diagnosed as a CI from 76% to 90% with an asymmetrical head shape, occipitoparietal flattening, and possibly, ear misalignment[23]. This ipsilateral frontal bossing is also directly described by level of deformity through CVAI measurements (as described above)[24,25]. While literature indicates the use of CVAI for describing brachycephaly and plagiocephaly, CVAI has not been used to accurately establish the presence of dolichocephaly[19,20,24]. According to the literature, dolichocephaly is best identified as a cranial index of less than 76% or lack of proportionality between head circumference and the biparietal diameter[19-21,23].

References

1. Crofton PM, Shrivastava A, Wade JC, et al. Bone and collagen markers in preterm infants: relationship with growth and bone mineral content over the first 10 weeks of life. Pediatr Res. 1999;46(5):581-587. doi:10.1203/00006450-199911000-00015
2. Sweeney JK, Gutierrez T. Musculoskeletal implications of preterm infant positioning in the NICU. J Perinat Neonatal Nurs. 2002;16(1):58-70. doi:10.1097/00005237-200206000-00007
3. Raghuram K, Yang J, Church PT, et al. Head growth trajectory and neurodevelopmental outcomes in preterm neonates. Pediatrics. 2017;140(1). doi:10.1542/peds.2017-0216
4. Ifflaender S, Rüdiger M, Konstantelos D, Wahls K, Burkhardt W. Prevalence of head deformities in preterm infants at term equivalent age. Early Hum Dev. 2013;89(12):1041-1047. doi:10.1016/j.earlhumdev.2013.08.011
5. Madlinger-Lewis L, Reynolds L, Zarem C, Crapnell T, Inder T, Pineda R. The effects of alternative positioning on preterm infants in the neonatal intensive care unit: a randomized clinical trial. Res Dev Disabil. 2014;35(2):490-497. doi:10.1016/j.ridd.2013.11.019
6. Brunherotti MA, Martinez EZ, Martinez FE. Effect of body position on preterm newborns receiving continuous positive airway pressure. Acta Paediatr. 2014;103(3):e101-5. doi:10.1111/apa.12504
7. Hough JL, Johnston L, Brauer SG, Woodgate PG, Pham TMT, Schibler A. Effect of body position on ventilation distribution in preterm infants on continuous positive airway pressure. Pediatr Crit Care Med. 2012;13(4):446-451. doi:10.1097/PCC.0b013e31822f18d9
8. Rivas-Fernandez M, Roqué I Figuls M, Diez-Izquierdo A, Escribano J, Balaguer A. Infant position in neonates receiving mechanical ventilation. Cochrane Database Syst Rev. 2016;11:CD003668. doi:10.1002/14651858.CD003668.pub4
9. Gillies D, Wells D, Bhandari AP. Positioning for acute respiratory distress in hospitalized infants and children. Cochrane Database Syst Rev. 2012;(7):CD003645. doi:10.1002/14651858.CD003645.pub3
10. Hough J, Trojman A, Schibler A. Effect of time and body position on ventilation in premature infants. Pediatr Res. 2016;80(4):499-504. doi:10.1038/pr.2016.116
11. Wu J, Zhai J, Jiang H, et al. Effect of change of mechanical ventilation position on the treatment of neonatal respiratory failure. Cell Biochem Biophys. 2015;72(3):845-849. doi:10.1007/s12013-015-0547-2
12. Jensen EA, DeMauro SB, Kornhauser M, Aghai ZH, Greenspan JS, Dysart KC. Effects of Multiple Ventilation Courses and Duration of Mechanical Ventilation on Respiratory Outcomes
13. McCarty DB, Peat JR, Malcolm WF, Smith PB, Fisher K, Goldstein RF. Dolichocephaly in preterm infants: prevalence, risk factors, and early motor outcomes. Am J Perinatol. 2017;34(4):372-378. doi:10.1055/s-0036-1592128
14. Schultz AA, Goodwin PA, Jesseman C, Toews HG, Lane M, Smith C. Evaluating the effectiveness of gel pillows for reducing bilateral head flattening in preterm infants: a randomized controlled pilot study. Appl Nurs Res. 2008;21(4):191-198. doi:10.1016/j.apnr.2006.11.003

15. Nuysink J, Eijsermans MJC, van Haastert IC, et al. Clinical course of asymmetric motor performance and deformational plagiocephaly in very preterm infants. J Pediatr. 2013;163(3):658-65.e1.
16. McCarty DB, O'Donnell S, Goldstein RF, Smith PB, Fisher K, Malcolm WF. Use of a midliner positioning system for prevention of dolichocephaly in preterm infants. *Pediatr Phys Ther*. 2018;30(2):126-134.
17. Hemingway M, Oliver S. Bilateral head flattening in hospitalized premature infants. Online J Knowl Synth Nurs. 2000;7:3.
18. Najarian SP. Infant cranial molding deformation and sleep position: implications for primary care. J Pediatr Health Care. 1999;13(4):173-177. doi:10.1016/S0891-5245(99)90036-6
19. Graham T, Millay K, Wang J, et al. Significant Factors in Cranial Remolding Orthotic Treatment of Asymmetrical Brachycephaly. *J Clin Med*. 2020;9(4):1027. Published 2020 Apr 5. doi:10.3390/jcm9041027
20. Kim, Dong Han MD; Kwon, Dong Rak MD, PhD∗ Neurodevelopmental delay according to severity of deformational plagiocephaly in children, Medicine: July 10, 2020 - Volume 99 - Issue 28 - p e21194 doi: 10.1097/MD.0000000000021194
21. Dunsirn S, Smyser C, Liao S, Inder T, Pineda R. Defining the nature and implications of head turn preference in the preterm infant. *Early Hum Dev*. 2016;96:53-60. doi:10.1016/j.earlhumdev.2016.02.002
22. Hutchinson, BL, Stewart, Alistair, Mitchell, Edwin characteristics, head shape measurements and developmental delay in 287 consecutive infants attending a plagiocephaly clinic Acta Paediatric 2009, Vo. 98, p. 1494-1499
23. Knight, S; Anderson, V;Meara, J; Da Costa, A Early Neurodevlopment in Infants With Deformational Plagiocephaly The Journal of Carniofacial Surgery Vol 24, Number 4, July 2013
24. Rogers, Gary F. Deformational Plagiocephaly, Brachycephaly, and Scaphocephaly. Part I: Terminology, Diagnosis, and Etiopathogenesis The Journal of Craniofacial Surgery Vol. 22, Number 1, January 2011
25. Growth Charts - Data Table of Infant Head Circumference-for-age Charts. https://www.cdc.gov/growthcharts/html_charts/hcageinf.htm. Accessed December 7, 2020.