Monitoring and Charting the
Head Size of Infants

To measure the occipitofrontal circumference (OFC), the most important physical dimension of an infant, extend a tape snugly around the head from the glabella to the external occipital protuberance and record the maximum reading. At term, the OFC is about 35 cm. The range for statistically defined normocephaly is ±2 standard deviations (SD) (Figure 53-1).

An OFC > 2 SD below the mean is microcephaly and > 2 SD above the mean is megaloccephaly (macrocephaly). The range between ±2 SD mostly reflects normal genetic variation in somatotype. During the first year of life, the OFC increases by an average of about 1 cm per month but most rapidly in the first 6 months. By 1 year of age, the infant’s OFC normally had increased about 12 cm, to around 47 cm. The brain weight nearly triples from 360 g at birth to about 950 g at 1 year, or about 70% of its final weight of 1,350 g.

Because a deviant OFC warns of an abnormal brain, measure every infant’s head regularly, starting at birth. In the first year of life, measure the OFC monthly, in the second year every 3 months, and in years 3 to 5 every 6 months. Plot the successive OFCs for comparison with the normal curve (Figures 53-1 and 2). When an infant has a small or large OFC on one measurement or when successive OFCs cross the graph lines upward or downward, always suspect an abnormal brain (see Figure 53-2).

The OFC of premature infants increases more rapidly for a period than in term infants, which is a normal phenomenon to distinguish from evolving hydrocephaly. Neonatology texts contain the appropriate curves for premature and very-low-birth weight infants. The OFC depends on the factors listed in Table 53-1.

Relation of OFC to Brain Size

Because an infant has a thin skull and the scalp and the sinuses are underdeveloped, the infant’s OFC correlates more closely with intracranial volume than in older people.

**FIGURE 53-1.** Normal curve for the occipitofrontal circumference of boys from term birth to 3 years. The occipitofrontal circumference (OFC) for girls is 0.5 to 1.0 cm less. The interrupted line is the mean. The solid lines are ±2 standard deviations. Data from Roche AF, et al. Head circumference reference data: birth to 18 years. Pediatrics 1987;79:706–12.
Microcephaly, a small head, necessitates micrencephaly—a small, underweight cerebrum or brain. In contrast, a large head may contain a large, overweight cerebrum as in megalencephaly; an underweight cerebrum as in hydrocephalus with a thinned cerebral wall; or no cerebrum, as in some patients with hydranencephaly, in whom the supratentorial space, while enlarged, contains only fluid. Thus, a given patient may have megalencephaly and micrencephaly if the pathologic process has both reduced the size of the brain and greatly increased the amount of fluid in or around it. Megalencephaly is a statistical description of head size, not a diagnosis and not a synonym for megalencephaly.

Brain Size and Intelligence

A rough correlation exists between brain size and scores on intelligence tests in normal individuals. College students with intelligence quotients (IQs) higher than 130 have slightly larger OFCs than otherwise normal students with IQs around 100. Apart from this fact, the degree that the OFC approaches or exceeds ± 2 SD increases the likelihood of an abnormal brain.

Microcephaly

Microcephaly, statistically defined, means an OFC > 2 SD below the mean for the person’s age and gender. Microcephaly implies neurologic impairment, but the OFC of 2.5% of normal people will fall below 2 SD, as will the OFC of pygmies and some dwarfs with normal intelligence. To evaluate the clinical significance of the OFC, consider gender, age, body size, and the family somatotype. Thus, we may distinguish a benign or asymptomatic familial microcephaly, which is a normal genetic variant, from symptomatic microcephaly with neurologic deficits.

Microcephaly may already exist at birth, and the head may remain small throughout the patient’s life. An OFC small at birth obviously implicates a prenatal cause. An OFC that is normal at birth but drops down across percentile lines suggests a perinatal or postnatal cause. If the OFC begins to drop across percentile lines several months after birth, suspect a progressive degenerative disease, inborn error of metabolism, systemic disease, or profound malnutrition. Nevertheless, some infants with dysgenetic or primary microcephaly may have a fairly normal OFC at birth that then fails to keep up with the normal growth curve.

Table 53-2 classifies microcephaly by causes identifiable from thorough clinical and laboratory investigations. However, the cause for microcephaly often remains unknown, in spite of an exhaustive work-up.

The agents that cause microcephaly may also cause megalencephaly due to hydrocephaly or due to excessive fluid accumulation in cysts or the meningeal spaces. In destructive microcephaly, a potentially normal brain has suffered a prenatal or perinatal insult, usually hypoxia or inflammation. Typical lesions in acquired microcephaly consist of single or multifocal porencephaly, thickened meninges, ventriculitis, periventricular calcifications, vasculitis, cortical laminar necrosis, ulegyria, or periventricular leukomalacia.

In dysgenetic or malformative microcephaly, an error occurs in chromosomal morphology or at the gene level. Typical malformations include macrogyria, microgyria, migratory disturbances, holoprosencephaly, lissencephaly, and agenesis of the corpus callosum. Viral infections, exogenous teratogens, and some inborn errors of metabolism can cause phenocopies of primary malformations.

Both genetic disorders and exogenous teratogens may cause microcephaly vera, a miniaturized brain that often has a coarse gyral pattern but a fairly normal overall contour and no overt destructive lesions or overt gross malformations.

<table>
<thead>
<tr>
<th>TABLE 53-1. Determinants of the Occipitofrontal Circumference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, sex, and genetic background</td>
</tr>
<tr>
<td>Volume of the intracranial contents</td>
</tr>
<tr>
<td>Brain weight and size, normal or as altered by disease</td>
</tr>
<tr>
<td>Amount of cerebrospinal fluid in the ventricles or subarachnoid space</td>
</tr>
<tr>
<td>Volume of intracranial blood</td>
</tr>
<tr>
<td>Space-occupying lesions</td>
</tr>
<tr>
<td>Ability of the sutures to expand</td>
</tr>
<tr>
<td>Thickness of the calvaria, scalp, and hair</td>
</tr>
</tbody>
</table>
TABLE 53-3. Procedures for Differential Diagnosis of Microcephaly

1. Complete history and physical examination of the patient.
2. Complete pedigree, obtained from grandparents as well as parents.
3. Inspect and measure all family members and perform a complete physical examination if indicated.
4. Inspect and measure all family members and perform a detailed physical examination.
5. Complete laboratory tests including TORCH screen and other maternal and fetal infections.
6. Perform TORCH screen and other maternal and fetal infections.
7. Perform TORCH screen and other maternal and fetal infections.
8. Perform TORCH screen and other maternal and fetal infections.
10. Perform TORCH screen and other maternal and fetal infections.
11. Perform TORCH screen and other maternal and fetal infections.
12. Perform TORCH screen and other maternal and fetal infections.
13. Perform TORCH screen and other maternal and fetal infections.

Communicating the Diagnosis and Prognosis to Parents

Meet with the parents in a private office, not in a hospital corridor or at the bedside. Begin by expressing concern that the infant may have a brain problem that may affect development. Speak conditionally, not dogmatically. First of all, demystify the diagnostic process. Parents always wonder, “Does this doctor really know what he is talking about?” They have heard stories of misdiagnoses or dismal prognoses that proved untrue. Clearly detail the evidence for your concerns, including the potential diagnosis, and laboratory test results. Often, I show the infant’s magnetic resonance imaging (MRI) scan to the parents, alongside a normal scan.

Never, ever declare that the infant is hopelessly retarded or is only a vegetable and belongs in an institution. Even with unequivocal lesions, such as a hydranencephaly, holoprosencephaly, or lissencephaly, the parents will resist and resent any such dogmatic declarations. Never insist that the parents institutionalize the infant. Let them ultimately raise that issue.

Having voiced and documented your concerns, enter into a parent–physician alliance to monitor whatever development might occur. Describe the development milestones to look for and their normal time of appearance. For example,
mention head control and ocular fixation and following. Explain that at follow-up visits, you will ask the parents about and check the baby for these achievements. Thus, physician and parents collaborate as equals in monitoring the infant's development. In this way, the parents themselves discover the infant's developmental fate. You have become an ally who helps confirm their own observations, not their adversary or merely the bearer of bad news.

Today's mixed families cause difficulties in obtaining the pedigree and in counseling because children can originate in four ways: his previous children, her previous children, their own children together, and neither of theirs (an adopted child). Thus, any given child may be his, hers, theirs, or neither's. Interns and young residents often fail to determine which children come from the current union and which come from previous unions and thus misinterpret the family history. Further difficulty arises when one mate, let us say the father, has had normal children by a previous union, but the first child with a new mother has a brain abnormality. The new mother may feel extreme anxiety, insecurity, and sometimes jealousy. This additional burden increases the guilt that, to some degree, afflicts most mothers of affected children. It makes the recriminating questions “What did I do wrong?” or “Why is God punishing me?” even more painful for the mother to face. The physician can comfort the mother by anticipating these states of mind and by explaining how little medical science knows about the exact causes of malformations, genetic errors, and teratogens. Point out the possibility that any couple can have a baby with brain abnormalities. Explain that reproduction carries an inherent risk that we cannot eliminate.

If some overt act of the mother, such as in fetal alcohol syndrome, has caused the brain defect, prepare to help the mother work through extreme guilt. Similarly, if the pedigree and the genetic work-up clearly establish one parent as the source of the defect, that parent will experience similar emotions. In such cases, it is helpful to explain that the genetic heritage of each one of us contains the potential for error. In one family the result is hypertension, in another, arthritis or cancer—and in another, a brain defect.

Because neurologically impaired infants may have trouble feeding and breathing and may require gastrostomy and respiratory assistance, consider early referral to a developmental center that offers such services as monitoring caloric intake and weight gain, physical therapy, speech therapy, and social support. Often, referral to a lay support group provides additional help.

**Megalencephaly and Megalencephaly**

Megalencephaly, statistically defined, means an OFC > 2 SD above the mean for the person's age and gender. Megalencephaly implies a neurologically defective individual, but the OFC of 2.5% of the normal population will exceed 2 SD. A common office problem, as with microcephaly, is to separate benign asymptomatic familial megalencephaly from symptomatic types. The OFC already may exceed 2 SD at the time of birth, or the infant may have a normal OFC at birth, and then it may accelerate upward (see Figure 53-2). Most megalencephalic patients have hydrocephaly or megalencephaly. Both conditions may cause successive OFC measurements to accelerate upward across graph lines (see Figure 53-2). Table 53-4 lists the most common causes of megalencephaly.

No known exogenous teratogens cause megalencephaly, although overweight babies of diabetic mothers may have large OFCs. Similarly, although dysgenetic causes for megalencephaly (such as fragile X syndrome, neurofibromatosis, and achondroplastic dwarfism) are fairly common, most dysgenetic syndromes, as well as exogenous teratogens, cause microcephaly rather than megalencephaly. Fragile X syndrome is second only to Down syndrome as a dysgenetic cause of retardation, but patients with Down syndrome have microcephaly.

**History and Physical Examination in Megalencephaly**

Determine whether the patient is improving developmentally or regressing. Regression indicates a worsening pathologic process, thus differentiating these patients, particularly those with evolving hydrocephaly, from those with static causes for megalencephaly. Inquire about poor feeding, vomiting, irritability, and a disturbed sleep pattern, which together suggest increased intracranial pressure. Carefully

**TABLE 53-4. Common Causes of Megalencephaly**

<table>
<thead>
<tr>
<th>Category</th>
<th>Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrocephaly</td>
<td>Malformation: Chiari’s malformation, aqueductal stenosis, arteriovenous malformation, or arachnoid cyst</td>
</tr>
<tr>
<td></td>
<td>Other: meningeal fibrosis, (postinflammatory or posthemorrhagic), dural sinus thrombosis, neoplasms, subdural fluid, extraventricular hydrocephaly (widened subarachnoid space), or porencephaly</td>
</tr>
<tr>
<td>Megalencephaly</td>
<td>Anatomic</td>
</tr>
<tr>
<td></td>
<td>Asymptomatic familial (upper 2.5% of the normal population)</td>
</tr>
<tr>
<td></td>
<td>Symptomatic familial</td>
</tr>
<tr>
<td></td>
<td>Metabolic: heredofamilial degenerative diseases</td>
</tr>
<tr>
<td>Subdural fluid</td>
<td>Posttraumatic hematoma, accidental injury, or child abuse</td>
</tr>
<tr>
<td>Hygroma</td>
<td></td>
</tr>
<tr>
<td>Empyema</td>
<td></td>
</tr>
<tr>
<td>Toxic-metabolic brain edema</td>
<td></td>
</tr>
<tr>
<td>Vitamin A intoxication</td>
<td></td>
</tr>
<tr>
<td>Tetracyclines</td>
<td></td>
</tr>
<tr>
<td>Lead poisoning</td>
<td></td>
</tr>
<tr>
<td>Idiopathic (pseudotumor cerebri)</td>
<td></td>
</tr>
<tr>
<td>Thickened skull</td>
<td>Familial bone dysplasia</td>
</tr>
<tr>
<td>Severe anemia</td>
<td></td>
</tr>
</tbody>
</table>
assess facial features for clues for craniofacioskeletal dysplasia syndromes. Survey the facial gestalt, the interorbital distance, and the proportions of the forehead, midface, and jaw. Determine the size and contour of the fontanelles and palpate the sutures. Increased intracranial pressure can cause a bulging fontanelle and widened sutures, whereas craniosynostosis causes closed, ridged sutures.

Physicians often mistakenly describe the normal anterior fontanelle as “flat.” With the infant relaxed and upright, the normal anterior fontanelle is slightly concave. A truly flat contour suggests some degree of increased intracranial pressure. In hydrocephaly, the fontanelle usually bulges, whereas in anatomic megalencephaly, it remains concave. In the metabolic types of megalencephaly, the fontanelle may also bulge. To judge the fontanelle contour, run the tip of your index finger across the fontanelle in the anteroposterior and lateral planes. The fingertip will dip down a little as it moves across the normal fontanelle. Also, a light beam that crosses the fontanelle tangentially will cast a shadow on the concavity of the normal fontanelle.

Attempt to transilluminate the head and complete the rest of the neurodevelopmental examination. Include a funduscopic examination through dilated pupils and a careful search of the skin surface for neurocutaneous stigmata, especially for the café-au-lait spots of neurofibromatosis, the ash-leaf spots of tuberous sclerosis, and multiple hemangiomas. Record the pedigree, as described for neurofibromatosis, the ash-leaf spots of tuberous sclerosis, and multiple hemangiomas. Record the pedigree, as described for major craniofacial abnormalities, including measurement of the OFC of near relatives, and examine their skin surfaces for neurocutaneous stigmata.

Laboratory Investigation of Megalocephaly
To quickly reduce the differential diagnosis to one of the five types listed in Table 53-4, first obtain an MRI scan of the head. For a premature or very young infant, an ultrasonographic scan may suffice for quick screening. MRI scans in benign anatomic megalencephaly may show ventricles that appear somewhat enlarged and wide subarachnoid spaces, neither of which require shunting or tapping. Next, consider the laboratory procedures listed in Table 53-3 for microcephaly.

If the patient has a dysplastic body or if an endocrine or metabolic disorder is suspected, consider radiography of the bones for configuration and bone age and a metabolic-endocrine work-up. Consider testing for blood vitamin A and lead levels, depending on the history.

Abnormal Head Shape
In the neonate, scalp edema (caput succedaneum) and molding of the head during birth are common causes of a misshapen head. Cephalohematomas are hemorrhages beneath the periosteum of one of the large flat bones of the calvaria, most commonly the parietal bone. They cause a localized bulge, limited by the line of a suture. The mass does not pulsate, differentiating it from a meningocele or any other lesion connected with the intracranial space.

Two of the commonest causes of misshapen heads apart from perinatal complications are positional molding and synostosis of the cranial sutures. Craniosynostosis alters the head shape by arresting growth at right angles to the plane of the closed suture. Sagittal suture synostosis results in scaphocephaly, a long, narrow calvaria. Coronal suture synostosis results in acrobrachycephaly, a short, broad cranium. Closure of both sutures causes oxycephaly and often microcephaly and restricted brain growth. Craniosynostosis, usually of the coronal suture, with malformations of the face and extremities, implies a genetic syndrome, such as Apert's syndrome (acrocephalosyndactyly).

Deformational or positional molding, with unilateral or unilaterial flattening of the occiput, can occur prenatally, or it can occur postnatally when an infant spends excessive time on the back or side. The prolonged positioning of normal infants on their backs to avoid sudden infant death syndrome results in some bilateral or unilateral flattening of the occiput. The heads of premature babies who lie on their sides increase in the anterior-posterior diameter (positional dolichocephaly). With any such positional molding, the sutures remain open. Disorders of the central nervous system or neuromuscular system that prolong the period of recumbency may also lead to unilateral or bilateral positional occipital flattening. Unilateral flattening of the occiput is called cranioscoliosis or plagiocephaly. Unilateral positional occipital flattening on the “down” side follows any condition that keeps the infant’s head to one side. Common associated conditions or causes of positional plagiocephaly include torticollis or a hemisindrome with a visual field defect or hemiplegia. Long-term follow-up studies show that a significant number of infants with plagiocephaly from any cause have developmental disabilities. Idiopathic and genetic forms of plagiocephaly also occur.

Unilateral positional or deformational flattening of the occiput torques or rotates the skull base, resulting in a lopsided skull. The occiput on one side appears flat, while the cheek and hemicranium on the same side extend forward. To check for this type of plagiocephaly, look down on the top of the infant’s head. The ear on the side of the forward cheek will sit forward of the opposite ear. If in doubt, insert the tips of your index fingers into the ear canals, pointing them straight inward. The axis of the finger in the ear on the side of the forward cheek will pass distinctly in front of the axis of the opposite ear canal. The much rarer type of plagiocephaly, craniosynostotic plagiocephaly, is caused by premature unilateral closure of the lambdoid suture. The unilateral suture closure restricts the forward growth of the
ipsilateral cheek and backward growth of the ipsilateral occiput, causing a small hemicranium and occipital flattening on that side. In addition to characteristic abnormalities in the shape of the head, craniosynostosis causes palpable ridging of one or more sutures.

When the physical examination discloses a misshapen skull, the next step is generally a computed tomography scan with bone windows to visualize the sutures and synchondroses. Obtain an MRI scan if the infant has any neurologic signs or developmental deficits. Obtain the scans early in infancy because surgical correction by linear craniectomy produces better cosmetic results in younger infants and presumably better functional results in patients with oxycephaly that restricts brain growth.

Deformational plagiocephaly tends to self-correct when the infant attains the vertical posture. Photographs of the misshapen head aid in documenting the initial severity of the condition and in monitoring any changes. Growth of the hair as the infant matures tends to conceal the abnormal skull shape, particularly in girls. If the infant lies consistently with the head turned to one side, the parent can orient the crib in such a way as to make the infant turn the head to the opposite side in order to observe the surroundings. For deformational plagiocephaly, the parents should prop up the infant and change the infant’s position frequently to avoid the full weight of the head on the occiput until the infant sits up. For severe deformational plagiocephaly, the parents may be referred to a pediatric physical therapy department to fit the infant with a head-molding helmet, although their efficacy is uncertain. Some parents may elect cosmetic surgery, but most patients are best managed conservatively. The only effective treatment for craniosynostotic plagiocephaly is surgery.

Suggested Readings


Practitioner and Patient Resources

National Hydrocephalus Foundation (NHF)
12431 Centralia Road
Lakewood, CA 90715-1623
http://www.nhfonline.org

The objectives of NHF are to assemble and disseminate information pertaining to hydrocephalus, its treatments, and outcomes; to establish and facilitate a communication network among affected families and individuals; to help others gain a deeper understanding of those areas affected by hydrocephalus, such as education, insurance, tax and estate planning, employment, and family; to increase public awareness and knowledge of hydrocephalus; and to promote and support research on the causes, treatment, and prevention of hydrocephalus.

National Center for Learning Disabilities (NCLD)
381 Park Avenue South, Suite 1401
New York, NY 10016
Phone: (212) 545-7510
Fax: (212) 545-9665
Toll-free: (888) 575-7373
http://www.ncld.org/index.html

The NCLD Web site strives to be an effective, easy-to-use resource for people seeking authoritative information on learning disabilities. The Web site includes a resource locator, fact sheets, research news, and much more.

National Institute of Neurological Disorders and Stroke (NINDS)
Microcephaly Information Page

Part of the National Institutes of Health, this Web site provides a list of organizations for information and support.

Family Village – Microcephaly Information
http://www.familyvillage.wisc.edu/lib_microc.htm

Family Village is a global community that integrates information, resources, and communication opportunities on the Internet for people with cognitive and other disabilities, for their families, and for those that provide them services and support. This Web site provides links for more information on microcephaly as well as online discussion groups.