VESTIBULAR RESPONSES TO ROTATION
IN THE NEWBORN INFANT

By MARGARET M. LAWRENCE, M.D.,* and CARL R. FEIND, M.D.t

New York City

THE need for exact knowledge of the normal vestibular response of young subjects to artificial stimulation became apparent to one of the authors while testing a group of patients with H. influenzae meningitis who had been treated with streptomycin. In addition to its importance in detecting vestibular damage caused by streptomycin, such information is of value in examining the cranial nerves of the newborn infant to identify congenital defects and birth injuries, and at later ages to confirm the presence of postnatal injuries and diseases.

To date, evaluation of the normal vestibular function in the newborn and young infant has been inadequate. This study is an attempt to perfect a technic or appraise the results of a simple vestibular test in infants and children.

This report concerns the vestibular response of 64 newborn infants to various stimuli. These infants were all healthy and were considered normal. Their ages varied from 3 hours to 10 days, and their weights between 2.2 to 4.0 kg. Sex and cultural background were disregarded. Caloric tests proved unsatisfactory at this age, because of smallness of the external canal and apparent discomfort to the infants manifested by their crying and tight closing of eyes, which made observation of nystagmus impossible. The following gives methods and results of rotation testing.

METHOD

The rotation apparatus used consisted of an electrically driven turntable actuated by a D C 1/4 H. P. motor, capable of turning in either direction and with a rheostat speed control. With its full load it was routinely accelerated to 30 rpm in 180° and braked to a stop in 45°. This table had been used in a previous streptomycin toxicity study and was modified to accommodate a well padded baby holder. The infant was placed supine on the platform (Fig. 1), with the head over the center of rotation. The head was extended 60° from the frontal plane of his body, so as to place the lateral semicircular canals in the plane of rotation, and was held between 2 loose padded muffs which allowed about 45° of rotation. The babies were rotated 10 times in 20 sec. Following a rest period of 3 to 5 min., rotation was repeated in the opposite direction.

The eyes were inspected before, during and after rotation. Eye deviation, nystagmus, head, neck and general body responses were noted.

RESULTS

The usual movements of the eyes before the beginning of rotation were slow and roving. Immediately after the onset of rotation the head turned in the opposite direction of rotation in all but 6 of the 64 cases. These 6 showed no movement. After a few turns...
many of the heads came back to a central position. Fifty-two of the infants kept their eyes open during the entire period of rotation. The eyes and heads of these were seen to deviate in the opposite direction to that of rotation and in this quadrant the eye exhibited a regular nystagmus with the fast component in the direction of rotation. This nystagmus started with acceleration and continued several turns. During the later period of rotating at a constant speed, the eyes in most cases returned to center or assumed their pretest roving with cessation of nystagmus. At the instant of braking (deceleration) the head and eyes rotated to the direction of turning and again nystagmus started, with the fast component now opposite to the direction of turning. Nystagmus, to acceleration and deceleration, was observed in 100% of the 64 cases. It was variable in rate and intensity but its direction was always parallel to the plane of rotation. Graph 1 contains a plot of the duration of postrotational nystagmus versus number of tests in 64 infants who were awake during the test. The duration of postrotational nystagmus varied from 3 to 35 seconds, and in any individual infant, was equal or within a few seconds in either direction except in three cases which were not further followed. It is probable that the reading of three seconds is inaccurate because the infant in whom it was observed had a 20 second response in rotation in the other direction, a value which according to the authors' findings is normal. The average postrotational nystagmoid response to 10 turns in 20 seconds was 13.1 seconds. Skin flushing, eructation and voiding were frequent during rotation. The above observations were checked by taking 16 mm. movies of a sizeable cross-section of the babies before, during, and after rotation. The movie camera and lights were rotated with the baby and included a picture of his face. (See Fig. 1.)

Eight infants were rotated both asleep and awake. The method used to observe the
eyes of all sleeping infants was as follows: An observer stood at the exact spot where the machine was stopped. The observer then separated the infant's eyelids and watched the eyes for a full minute. None of the babies who were asleep during the test had any post-rotational nystagmus, nor did five others not included in the series of 64, who were rotated asleep only. The eight infants were also described in the preceding awake group.

Failure to respond to vestibular stimulation during sleep was previously observed by one of the authors in a 4½ month old infant who did not respond to 30° or 44°C. water (Hallpike Fitzgerald test), to rotation at 60 rpm, nor to 100 cc. of ice water in one ear. The child remained sound asleep during all of the above procedures, but during irrigation of the second ear with ice water the child stirred and awakened. At this time, the eye under observation, which had been rolled up, came down and immediately went into regular rapid medium nystagmus. The other tests repeated while awake were all within normal limits. In the series of 64, there was no difference in response in relation to age or weight.
The authors have found this method of rotation a useful one for the study of vestibular function in the newborn infant. The apparatus used is simple to construct, convenient to manage, and gives consistent results, in contrast to hand rotation using the Bárány chair.

**Comment**

Few references to vestibular responses in the newborn infant can be found in the literature and the reports are conflicting as to the presence of nystagmus. Ford states that reactions to rotation or rotary acceleration are present at birth. However, he does not describe these responses. Magnus, in his description of responses to rotation in newborn animals, found that nystagmus could be observed at 18 days in the rabbit, at 4 or 5 weeks in the dog and at 6 and 7 days in the cat. Bartel described eye deviation but no fast component of nystagmus in newly born premature human infants; full term newborn infants, on the other hand, showed normal nystagmus in response to rotation. DeKleyn and Schenk in 1931 reported their findings on rotating a one week old anencephalic child. Their method of rotation was to hold the infant by the trunk with his head in the upright position; the observer and the child then turned about a vertical axis. Turning to the right caused a postrotation fast component of nystagmus to the left; likewise rotating to the left resulted in nystagmus to the right. This infant, as shall be commented on later, lacked cerebral hemispheres, cerebellum, and third and fourth nerve nuclei.

McGraw, as a part of a more comprehensive study, observed the postural and ocular responses of the infant to bodily rotation. This study included 67 infants from birth to 2 years. The child was held in an upright position facing the experimenter, and both turned together, the experimenter pirouetting. No attempt was made to stimulate "particular vestibular canals." The speed of turning was calculated to be 0.778 rotations per second; body and ocular deviation were recorded by direct observation. Three types of response were described: A phase during which the eyes deviated laterally in the direction of rotation during the movement and in the opposite direction after rotation had ceased; this "phase" occurred in 100% of the infants under about one month of age. A gross oscillatory phase (Phase B) at about the fourth month in which the eyes showed coarse slow horizontal excursion during rotation, continuing for a few seconds after rotation was stopped. A fine oscillatory phase (Phase C) during rotation, occurring around the seventh month. No mention was made of how optokinetic nystagmus was eliminated during rotation in the older age group. Also there was no control of acceleration, speed or deceleration with this method.

McGraw posits that the "changing adjustments of the infant to rotation indicate reorganization of the neural system involved," and states that there is considerable doubt that the cerebral cortex exercises much influence upon these labyrinthine reflexes. Ford, on the basis of the work of Langworthy, states that "with some exceptions the anatomical development of the segmental apparatus is complete at birth" and that "the chief supra-segmental structures and their projection paths are still immature." We should expect, then, that vestibular responses in the newborn infant would be purely a response of the archaic motor system, a name used by Gesell for the early response systems, and that this archaic motor system would be free of cerebral inhibition. Again interpreting Langworthy's work, Ford states that the lack of cerebral function in the newborn infant is expressed in two ways: absence of true volitional activity and lack of inhibition of the segmental apparatus.

We should expect, too, that the vestibular system would be entirely capable of func-
tioning on its own since the neurons involved are among the earliest to become myelinated, beginning as early as a fetal age of 20 to 24 weeks (Langworthy). The neurons involved in nystagmus produced by stimulation of semicircular canals are the third, fourth, sixth, and the vestibular part of the eighth cranial nerves and the median longitudinal fasciculus. Furthermore, according to Langworthy, the sequence in which tracts become myelinated is correlated with the sequence in which the function of structure develops. The anencephalic child described by deKleyn and Schenk, who at one week of age exhibited both components of nystagmus, proves the ability of this archaic vestibular apparatus to function independently of cerebral influence. Only the reflex connections, labyrinths, vestibular and abducens nuclei were present; the cerebral hemispheres, cerebellum, and third and fourth nerves were absent.

The group of 64 newborn infants described in this report can be compared to McGraw's newborn group. As has been noted, McGraw's newborn infants were said to show "Phase A" postrotation response consisting of head and eye rotation toward the direction opposite to that of rotation. The post-rotation findings of the present investigators were eye deviation to the direction of turning and a fast component (nystagmus) opposite to the direction of turning. The rotation apparatus used made it possible to observe the eye responses of infants with comparative ease and to obtain consistent results in this study. Other observers have reported eye movements in the newborn infant, in response to rotation, but they have not reported in detail concerning the presence of the fast component (nystagmus), its duration, direction and associated movements.

A careful review of the available reports on vestibular responses to rotation in adults reveals no work on an adult group comparable to that done by the present authors with newborn infants. Speed of rotation, rate of acceleration and rate of deceleration were all kept constant in the present study. None of the methods described in the rotation of adults has kept these factors constant. Because these important factors are variable, it is difficult to compare the results of these tests on adults with each other or with those done on this newborn group. Northington describes a rotation test for adults in which the same semicircular canals are stimulated as in this study. In the adult test the individual is in a face-front seated position with the head flexed 30°. In both instances the horizontal semicircular canal is in the same plane as the plane of rotation. The Bárány chair used for testing adults is rotated by hand 10 times in 20 seconds. Northington found that the duration of the postrotatory nystagmus varied from 15 to 31 seconds and in the majority from 15 to 20 seconds. The average postrotational nystagmus is 18 seconds in duration. In adults amplitude is usually rated as fine, medium or coarse, and the frequency as fast, medium or slow. These observations are rather inaccurate and vary with the observer. It is, however, the impression of one of the authors that the response in the newborn infant is of greater amplitude, slower frequency, and shorter in duration than in adults. The need for standardized and controlled rotation tests, and permanent recordings of eye movements is great. When these improvements are worked out and normal responses are tabulated for large groups, then vestibular tests will become more meaningful as a diagnostic aid. A permanent recording of eye movements other than motion pictures, but more like an EEG or ECG will eliminate the inaccuracies of observers and give exact measurements of duration, frequency and amplitude. At this writing several approaches to the problem are being investigated by Dr. Edmund P. Fowler, Jr.
VESTIBULAR RESPONSES TO ROTATION

SUMMARY

Using a newly designed rotating apparatus with control of acceleration, deceleration and speed, the response of 64 full term newborn infants to rotation was studied.

While awake, all infants showed head and eye deviation opposite to the direction of rotation during acceleration and in the same direction during deceleration; all infants had a normal nystagmus during acceleration and for several turns of constant speed. Then followed a reversal of the nystagmus as soon as deceleration took place. The duration of postrotational nystagmus following 10 turns in 20 seconds varied from 3 to 35 seconds with an average of 13.1 seconds. There is no comparable adult group reported as the stimulus is not constant or controlled.

Sleeping infants had no response to rotation even though they gave normal responses while awake.

Associated postrotation reactions were: flushing, eructation and voiding.

The literature on vestibular responses to rotation in the newborn infant has been reviewed.

ACKNOWLEDGMENT

The authors wish to thank Dr. Edmund P. Fowler, Jr., for his guidance and sponsorship of this project.

REFERENCES


SPANISH ABSTRACT

Respuestas Vestibulares a la Rotación en Niños Recién Nacidos

Al examinar un grupo de pacientes con meningitis a hemofilus influenzae tratados con estreptomicina se vió la necesidad de conocer mejor la respuesta vestibular normal de los lactantes a la excitación artificial; al mismo tiempo que se analiza el daño causado por la estreptomicina se pueden estudiar los nervios craneales para identificar defectos congénitos, lesiones de nacimiento en el recién nacido, o bien confirmar la presencia de lesiones y enfermedades post natales en edades mayores. Los autores presentan este estudio como un esfuerzo para perfeccionar una técnica que valore los resultados de una sencilla prueba vestibular en lactantes y niños.

Se estudiaron 64 niños recién nacidos sanos y normales, con edades variables de tres horas a diez días y pesos de 2.2 a 4 kilogramos, sin considerar el sexo ni el grado cultural familiar.

Se empleó un aparato de rotación con control de la velocidad, tanto para aumentarla como
disminuírla o sostenerla; se rotó a los niños 10 veces en 20 segundos y después de un descanso de 3 a 5 minutos, la rotación se repitió en dirección opuesta. Se observaron los ojos, antes, durante y después de la rotación, anotándose desviaciones oculares, nistagmus, respuesta de la cabeza, del cuello y del cuerpo.

La literatura no presenta más que pocas observaciones de las respuestas vestibulares en el recién nacido y los informes son contradictorios en cuanto a la presencia del nistagmus.

Todos los niños examinados por estos autores mostraron durante la vigilia desviación de la cabeza y de los ojos en sentido opuesto a la dirección de la rotación durante la aceleración, y en la misma dirección durante la disminución de la velocidad; todos presentaron un nistagmus normal durante la aceleración y durante varias rotaciones a una velocidad sostenida, pero el nistagmus se invirtió al disminuir la velocidad. La duración del nistagmus después de 10 vueltas en 20 segundos varió de 3 a 35 segundos, obteniéndose un promedio de 13.1 segundos. No se tiene conocimiento de un estudio comparable en un grupo de adultos.

No se observaron respuestas a la rotación cuando los niños dormían a pesar de que su respuesta fue normal en la vigilia. Las reacciones observadas después de la prueba fueron: enrojecimiento, eructación y micción urinaria.

19 Hamilton Terrace
VESTIBULAR RESPONSES TO ROTATION IN THE NEWBORN INFANT
MARGARET M. LAWRENCE and CARL R. FEIND

Pediatrics 1953;12;300

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://pediatrics.aappublications.org/content/12/3/300