

THE DUBOWITZ NEUROLOGICAL EXAMINATION OF THE FULL-TERM NEWBORN

Lilly Dubowitz,¹ Daniela Ricci,² and Eugenio Mercuri^{1,2*}

¹Department of Paediatrics, Hammersmith Hospital, Imperial College, London UK,

²Child Neurology Unit, Department of Paediatrics, Catholic University, Rome, Italy

In an ideal world, each neonate should have a comprehensive neurological examination but in practice this is often difficult. In this review we will describe what a routine neurological evaluation in the full-term neonate should consist of and how the Dubowitz examination is performed. The examination has been used for over 20 years and can be easily performed in a short time as the recording sheet provides simple instructions together with simple diagrams to make the recording and the scoring easier. We will also indicate how the examination can be used to identify infants with neurological abnormalities, describing clinical signs which can help to differentiate infants with peripheral neuromuscular disorders from those with central nervous system involvement. The correlation between clinical and imaging findings in infants with neonatal brain lesions will also be reported. Finally we will briefly describe how and when to apply an optimality scoring system in a research setting.

© 2005 Wiley-Liss, Inc.

MRDD Research Reviews 2005; 11:52–60.

Key Words: neonatal examination; preterm infants; perinatal brain lesions; optimality score

At the time when we developed our examination in 1981, most current examinations focused on specific aspects of neurological function. The French school mainly assessed tone and primitive reflexes [Andre-Thomas et al., 1960; Saint-Anne Dargassies, 1977; Amiel-Tison and Grenier, 1980], while others concentrated more on various aspects of behavior [Brazelton, 1973; Prechtl, 1977; Casaer, 1979; Prechtl et al., 1997]. Another problem has been that, although these methods have brought considerable advance to the assessment of the newborn, they required experienced staff with special training and often took a considerable time to perform and thus were poorly suited for routine use. Our aim was to develop a more general examination which would encompass various aspects of neurological function, such as behavioral states, tone, primitive reflexes, motility, and some aspects of behavior. We aimed for our examination to be quick and practical, easy to perform and to record, and applicable in the first few days of life even to preterm infants in an incubator. This would mean that it could be easily used as a component of the routine clinical evaluation of both preterm and full-term newborn infants.

The assessment has been used for over 20 years in both clinical and research settings and has recently been updated according to the experience collected during those years [Dubowitz et al., 1998, 1999]. While we found that the basic scheme proved to be very successful, in particular in relating lesions to neurological patterns and documenting longitudinal

neurological impairment and recovery, a number of the items were found difficult to elicit, while others, although easily elicited, proved to be relatively superfluous [Dubowitz et al., 1999]. By using the examination as part of an integrated approach with neuroimaging, we also found that other items, such as those assessing relative distribution of tone, can be very useful to identify infants with severe neurological abnormalities. Following these changes the proforma has been generally restructured. The revised version of the examination, published in 1999, includes 34 items subdivided into 6 categories (tone, tone patterns, reflexes, movements, abnormal signs, and behavior).

TYPICAL DURATION OF TEST

The full examination and its recording should not take longer than 10 to 15 minutes.

TRAINING REQUIRED

We have found that no formal training is required as the examination has been easily performed even by inexperienced people by following the instructions included in the recording proforma.

The test has been designed using a format that makes it easy to perform and record. It is presented in a recording sheet (proforma) in which simple instructions for each item are given together with some simple diagrams to make the scoring easier. The proforma is easily scored by circling the description or the figure that best fits the infant's state.

In practice, it is often easy to eliminate the obviously inappropriate descriptions so that one is left with a choice between two possibilities. If it is still difficult to decide between the two choices, it may be appropriate to ring both. If the findings cannot easily be matched to a diagram, the nearest appropriate figure can be circled. If a deviation is observed, a drawing of it can be superimposed on the figure. With some items, such as posture and type of mobility, which are not static but constantly changing, we try to record the predominant status during the examination.

*Correspondence to: E. Mercuri, Department of Pediatrics, Hammersmith Hospital, Du Cane Road, London W12 0HN, United Kingdom. E-mail: e.mercuri@ic.ac.uk
Received 9 December 2004; Accepted 16 December 2004
Published online in Wiley InterScience (www.interscience.wiley.com).
DOI: 10.1002/mrdd.20048

POSTURE Infant supine, look mainly at position of legs but also note arms. <i>score predominant posture</i>	arms & legs extended or very slightly flexed 	legs slightly flexed 	leg well-flexed but not adducted 	leg well flexed & adducted near abdomen 	abnormal posture: a) opisthotonus b) 
--	---	---	---	--	---

Fig. 1. Item assessing posture.

If further help is required, more detailed instructions and practical tips, are available in the manual [Dubowitz et al., 1999], where the test procedures and its application are more fully described.

INTERRATER RELIABILITY

The examination can be easily performed following the instructions. The interrater reliability is above 96% even with inexperienced staff [Dubowitz et al., 1999; McGready et al., 2000].

DESCRIPTION OF TEST PROCEDURE

The assessment is best performed two-thirds of the way between feeds when the infants are more likely to be in an optimal state. Preterm infants on continuous feeding (intravenous or alimentary) can be examined at any time.

After uncovering the infant, the examination should start with a period of observation. During this, the posture of head, trunk, and extremities and spontaneous movements can easily be assessed. The observation should also include any abnormal pattern of movements of the respiratory muscles and the possible presence of joint contractures. At this stage the infant should also be inspected for the evidence of any trauma or malformations. These findings should be listed as "other signs" at the end of the proforma. Head circumference and size of the fontanel should be also noted on the proforma.

Posture and Tone

Posture

After gently uncovering the infant and taking off or loosening the diaper while the infant is lying in the supine position, head in midline, the predominant posture in a quiet state should be recorded (Fig. 1).

Limb tone is assessed by noting the tone of the limbs in the supine position and in ventral suspension and by the response to traction of the upper and lower limb with the infant lying in the supine, head in the midline (Fig. 2). To elicit arm

traction the arm is pulled slowly to a vertical position by the wrist. The resistance and the angle of flexion at the elbow is noted when the shoulder lifts from the surface. Leg traction is elicited by raising the leg into vertical position by gentle traction on the ankle. The resistance to this maneuver and the angle of flexion at the knee are noted when the buttock becomes elevated. Both arm and leg traction are tested separately in each limb.

Trunk and neck tone are evaluated by assessing (a) *head control* in the sitting position, (b) *head lag* while the infant is pulled to the sitting position, and (c) the *posture of the head and trunk in ventral suspension* (Fig. 3).

Head control in the sitting position is elicited by placing the infant into a sitting position and holding it there by encircling the infant's chest with the examiner's hand, then allowing the head either to fall forward (head control 1) or backward (head control 2). The infant's ability to raise the head to vertical is noted.

Head lag is elicited by grasping the infant's wrists and gently pulling the infant from the supine toward the sitting position. The response of the head to this maneuver is noted.

Posture of the head and trunk in ventral suspension is tested by suspending the infant in the prone position by a hand under the chest. Posture of the head in relation to the trunk is scored and the amount of flexion in the arms is also noted. The diagram most resembling the position of the trunk should be circled and any deviation of head or limb posture from the diagram in the proforma should be drawn on the diagram.

Maturation of tone

Posture and tone are age dependent, reflecting the increase in flexor tone in the limbs and in axial tone with increasing maturity. Flexor tone of the neck muscles can be demonstrated from about 28 weeks' gestation onward but good extensor tone in the neck muscles often cannot be demonstrated until term.

When examined at term age, preterm infants tend to have less flexor tone in the limbs than full-term infants. The range of scores is lower both on traction and recoil, especially in the upper limbs. The assessment of head control in the sitting posture shows less extensor tone in the neck compared to full-term infants [Mercuri et al., 2003].

Assessment of tone patterns

It is important that the items assessing tone are evaluated not only individually but also compared to each other in order to identify possible patterns of distribution of tone (Fig. 4). This will help to establish, for example, whether the infant has generalized hypotonia or only poor axial tone (reduced trunk and head control). While the former may also be associated with systemic illness, central nervous system (CNS) involvement, and neuromuscular disease, the latter is more often a marker of CNS involvement.

In the revised version of the examination we included four new items assessing differential tone in order to highlight some aspects that, in our experience, are very different in full-term and preterm infants with brain lesions compared to the normal infant and hence are very important to assess [Mercuri et al., 1999].

Predominance of extensor tone compared to flexor tone. This is assessed comparing ventral suspension and head lag or neck flexor and extensor muscles in the two items assessing head control.

Relative increase in the neck extensor muscles compared to the flexor ones is often associated with hypoxic-ischemic lesions, meningitis, or increased intraventricular pressure.

Differential distribution of tone in upper and lower limbs. This is assessed comparing tone of upper and lower limbs (Fig. 5).

Abnormal patterns of leg tone are often observed in infants with breech presentation or in normal crying infants. If noted in a quiet infant at any

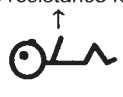
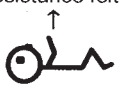
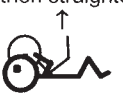
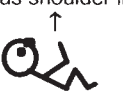
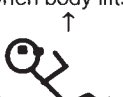
ARM RECOIL Take both hands, quickly extend arms parallel to the body. Count to three. Release. Repeat X 3	arms do not flex 	arms flex slowly, not always; not completely 	arms flex slowly; more complete 	arms flex quickly and completely 	arms difficult to extend; snap back forcefully
ARM TRACTION Hold wrist and pull arm upwards. Note flexion at elbow and resistance while shoulder lifts off table. <i>Test each side separately</i>	arms remain straight; no resistance felt 	arms flex slightly or some resistance felt 	arms flex well till shoulder lifts, then straighten 	arms flex at approx 100° & maintained as shoulder lifts 	flexion of arms <100°; maintained when body lifts up 
LEG RECOIL Take both ankles in one hand, flex hips+ knees. Quickly extend. Release. Repeat X3	No flexion 	incomplete or variable flexion 	complete but slow flexion 	complete fast flexion 	legs difficult to extend; snap back forcefully
LEG TRACTION Grasp ankle and slowly pull leg upwards. Note flexion at knees and resistance as buttocks lift. <i>Test each side separately</i>	legs straight - no resistance felt 	legs flex slightly or some resistance felt 	legs flex well till bottom lifts up 	knee flexes remains flexed when bottom up 	flexion stays when back+bottom up 
POPLITEAL ANGLE Fix knee on abdomen, extend leg by gentle pressure with index finger behind the ankle. Note angle at knee. <i>Test each side separately</i>	 180°	 ≈ 150°	 ≈ 110°	 ≈ 90°	 < 90°

Fig. 2. Items assessing limb tone.

gestation it should raise the suspicion of CNS pathology. This sign can be associated with a number of conditions, such as the onset of an intraventricular hemorrhage or periventricular leukomalacia, and is often observed in full-term infants with hypoxic-ischemic encephalopathy who have severe basal ganglia lesions on brain MRI.

Relatively tight popliteal angle compared to leg traction. This is assessed comparing popliteal angle and leg traction (Fig. 6).

A tight popliteal angle associated with relatively poor resistance on leg traction can be observed in infants with breech presentation. A disproportionately tight popliteal angle compared with the rest of the leg tone is frequently found in association with germinal matrix or intraventricular hemorrhages.

Reflexes

Eliciting primitive reflexes has been regarded as an important compo-

nent of the neurological assessment of the newborn. However, in our experience, reflexes cannot reliably identify infants with neurological abnormalities, as abnormal reflexes can be observed in normal infants and normal reflexes can also be found even in grossly abnormal infants. We have therefore decided to retain only the reflexes that we considered to be the most useful for our purpose (Fig. 7) [Dubowitz et al., 1999].

Maturation of reflexes

Palmar grasp is present from 27 and 28 weeks' postmenstrual age and becomes much stronger with increasing maturity.

Plantar grasp is present from 26 weeks' postmenstrual age and becomes only slightly stronger with increasing maturity.

Placing reaction can be observed generally from 34 weeks' postmenstrual age and becomes more pronounced in the following 2–4 weeks.

Moro reflex at 25–27 weeks' postmenstrual age only consists of the opening of the hands. With increasing maturity, extension and abduction of the upper extremity can be noted, followed by some adduction at the shoulder from 33 to 34 weeks' postmenstrual age. The adduction gradually becomes stronger.

Sucking reflex is already present at 27–28 weeks' gestation but during the next few weeks it becomes more powerful and better coordinated with swallowing. By 32–34 weeks a normal infant should be able to feed orally.

Movements

These are best observed with the infant in the supine, preferably while awake and quiet. Observations should be carried out throughout the examination and scored when the most suitable state is achieved. Both quality and quantity of spontaneous movements are noted (Table 1). It is also important to

HEAD CONTROL (1) (extensor tone) Infant sitting upright; Encircle chest with both hands holding shoulders. Let head drop forward.	no attempt to raise head 	infant tries: effort better felt than seen 	raises head but drops forward or back 	raises head: remains vertical; it may wobble 	
HEAD CONTROL (2) (flexor tone) Infant sitting upright; Encircle chest with both hands holding shoulders. Let head drop backward.	no attempt to raise head 	infant tries: effort better felt than seen 	raises head but drops forward or back 	raises head: remains vertical; it may wobble 	head upright or extended; cannot be passively flexed
HEAD LAG Pull infant to towards sitting posture by traction on both wrists & support head slightly. Also note arm flexion	head drops & stays back 	tries to lift head but it drops back 	able to lift head slightly 	lifts head in line with body 	head in front of body 
VENTRAL SUSPENSION Hold infant in ventral suspension; observe back, flexion of limbs and relation of head to trunk. If it looks different, DRAW	back curved, head & limbs hang straight 	back curved, head ↓, limbs slightly flexed 	back slightly curved, limbs flexed 	back straight, head in line, limbs flexed 	back straight, head above body 

Fig. 3. Items assessing axial tone.

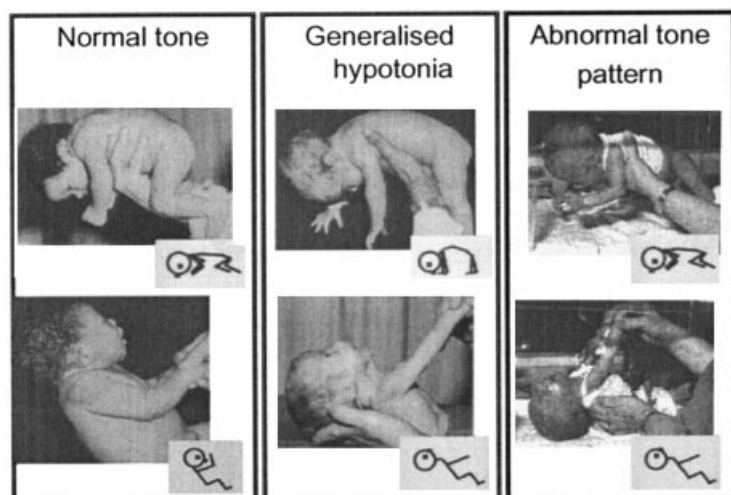


Fig. 4. Tone patterns (extensor tone).

observe the presence of antigravity movements as this is an important sign in the differential diagnosis of floppy infants. In addition, attention should be paid to the presence of any abnormal movements, such as abnormal eye movement, twitching, or jitteriness, as the latter ones in particular might be sign of abnormalities such as convulsions or hypoglycemia, which might require intervention.

Maturation of movements

Movements in the premature infant often consist of stretching and twisting of the trunk and limb, often associated with repetitive wide-amplitude movements of the limbs, resembling myoclonus. Both the quality and quantity of spontaneous movements change with gestational age and there is an increase in the quantity of the movements and a gradual change of their pattern with a

tendency toward smooth, alternating movements of the arms and legs.

When examined at term age, premature infants also have more jerky movements, *tremors*, and startles than full-term infants [Mercuri et al., 2003].

Neurobehavioural Items

This section includes assessment of visual and auditory orientation, which, when abnormal, are important signs of suspected CNS involvement (Fig. 8). These items are checked when the infant is awake or can be roused to a quiet awake state (state 4 according to Brazelton [1973]) and should be retested if in doubt that the response achieved was state dependent. The level of alertness is not based on the infant's appearance but on the response to stimuli, in particular visual stimuli.

Irritability and consolability provide a clear reflection whether the infant is unresponsive, apathetic, and difficult to rouse or is overresponsive, hyperirritable, and difficult to console. Either can reflect an abnormal neurological state.

We have also added two other items to this section: eye movements and quality of the infant's cry, although they are not really neurobehavioral items, they are best observed while scoring the rest of the neurobehavioral examination. Weak cry and

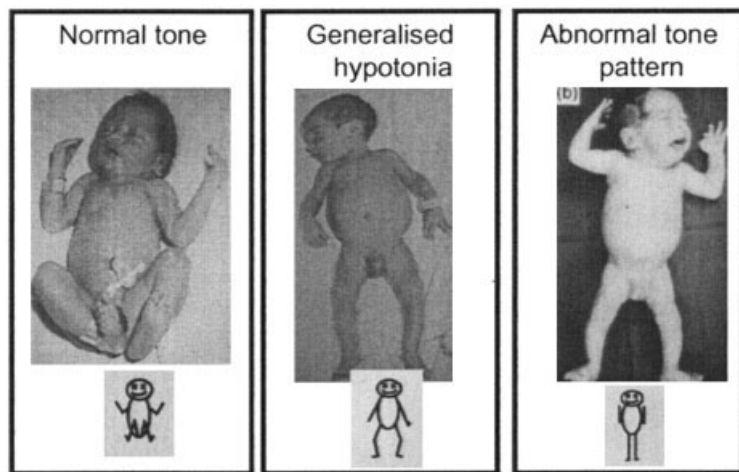


Fig. 5. Tone patterns: increased leg extension and arm flexion.

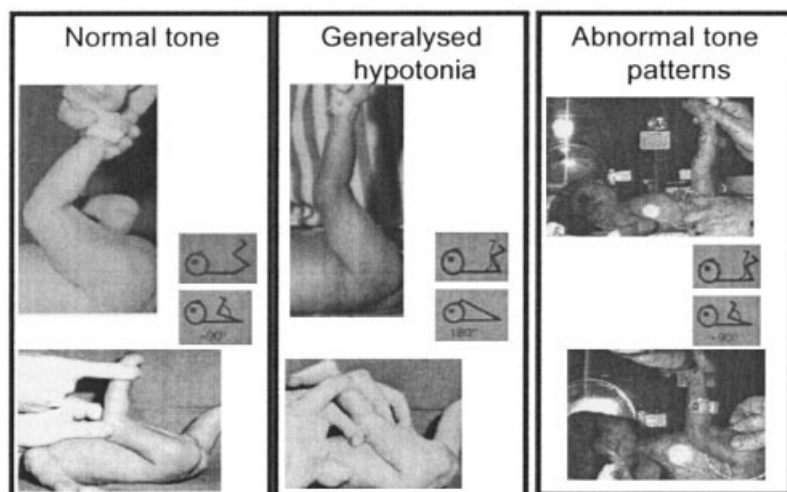


Fig. 6. Differential tone between popliteal angle and leg traction.

high pitched cry also reflect an abnormal neurological state.

Maturation of behavioral items

Even prior to 32 weeks' gestation, some preterm infants can focus on a target but they are usually not yet able to track. After 32 weeks many of them are able to track horizontally or vertically and by 36 weeks many of them can track even in an arc.

A response to an auditory stimulus can be elicited from 27 to 28 weeks' postmenstrual age and becomes stronger with increasing gestational age.

When examined at term age, preterm infants have more variable responses on items assessing visual behavior but there is a higher percentage of preterm infants who are able to follow in a full circle than in full term [Mercuri et al., 2003].

Other Abnormal Signs

This section includes a list of signs that need checking as their presence is often suggestive of an underlying CNS involvement (Fig. 9). These include abnormal hand or foot posture and the presence of tremors and startles.

DESCRIPTION OF SCORING SYSTEM

As part of the routine examination, each item is scored according to the criteria previously described. In every day clinical practice the pattern of the examination on the scoring sheet will give a good guide to the infant neurological state. Repeated examination and comparison of the pattern will in particular suggest improvement or deterioration.

We have recently also proposed an optimality score to be mainly used in research settings, when a more quantita-

tive assessment is required. This score has been standardized in full term infants examined in the first 48 hours following birth [Dubowitz et al., 1998] and is based on the distribution of the scores for each individual item in the population of low-risk full-term infants. Using cut-off points of 10th and 5th centile, we have therefore been able to define only the most common pattern for each item. A total optimality score can be obtained by summing the optimality scores of individual items. The analysis of the total optimality scores in our low-risk population revealed that suboptimal results on one or two single items can be observed in a third of this normal population while the association of four or more suboptimal scores was found in less than 10% of our infants, suggesting that isolated deviant signs have little diagnostic value.

The optimality score in its present form has been only validated in full-term infants in the first days of life and can therefore only be used in similar cohorts [Dubowitz et al., 1999]. We have recently reported the application of the optimality system to a cohort of low-risk preterm infants reaching term. We found that the findings in preterm infants at term age are more variable than in full-term infants, as preterm infants at term age have less flexor tone and overall better response to behavioral items [Mercuri et al., 2003].

APPLICATION OF THE EXAMINATION AND SIGNIFICANCE

There are several factors that might influence the interpretation of whether a specific finding is normal or abnormal. The obvious ones are illness, convulsions, or medications, but others, such as knowledge of the correct gestational age of the child and the postnatal age, have to be taken into account.

Infants with Neurological Abnormalities

The examination can be used to detect abnormal neurological signs in infants with lesions in the central and peripheral nervous system. A detailed neurological examination can help to differentiate infants with neuromuscular disorders from those with CNS involvement [Mercuri et al., 2001]. The examination can also document and identify clinical signs associated with specific patterns of lesions seen on brain imaging.

Neuromuscular disorders

In newborns with neuromuscular disorders, generalized hypotonia is usu-

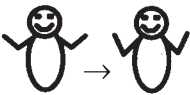
TENDON REFLEX test biceps, knee and ankle jerks.	absent	felt, not seen	seen	'exaggerated'	clonus
SUCK / GAG Little finger into mouth with pulp of finger upwards.	no gag / no suck	weak irregular suck only: No stripping	weak regular suck Some stripping	strong suck: (a) irregular (b) regular Good stripping	no suck but strong clenching
PALMAR GRASP Put index finger into the hand and gently press palmar surface. Do not touch dorsal surface.	no response R L	short, weak flexion of fingers R L	strong flexion of fingers R L	strong finger flexion, shoulder ↑ R L	very strong grasp; infant can be lifted off couch R L
PLANTAR GRASP Press thumb on the sole below the toes.	no response R L	partial plantar flexion of toes R L	toes curve around the examiner's finger R L		
PLACING Lift infant in an upright position and stroke the dorsum of the foot against a protruding edge of a flat surface. <i>Test each side separately</i>	No response R L	dorsiflexion of ankle only R L	full placing response with flexion of hip, knee & placing sole on surface R L		
MORO One hand supports infant's head in midline, the other the back. Raise infant to 45° and when relaxed let his head fall through 10°. Note if jerky. Repeat 3 times	no response or opening of hands only	full abduction at shoulder and extension of the arms; no adduction 	full abduction but only delayed or partial adduction 	partial abduction at shoulder and extension of arms followed by smooth adduction 	• no abduction or adduction; • only forward extension of arms from the shoulders • marked adduction only  or 

Fig. 7. Items assessing reflexes.

TABLE 1. Items Assessing Movements.

SPONTANEOUS MOVEMENT (quantity) Watch infant lying supine	no movement	sporadic and short isolated movements	frequent isolated movements	frequent generalised movements	continuous exaggerated movements
SPONTANEOUS MOVEMENT (quality) Watch infant lying supine	only stretches	stretches and random abrupt movements; some smooth movements	fluent movements but monotonous	fluent alternating movements of arms + legs; good variability	• cramped synchronised; • mouthing • jerky or other abn. mov.

ally associated with muscle weakness. This is best assessed by looking for the presence or absence of antigravity movements. A useful observation is that infants with neuromuscular disorders will show

few changes in their movement pattern, even in response to pain or when crying. In contrast, children with CNS involvement may show a similar floppy posture, but they have isolated antigravity move-

ments in response to stimulation. Elicitation of reflexes can also be useful; absent reflexes in a floppy infant strongly suggest a severe motoneuron disorder [Mercuri et al., 2001].

EYE APPEARANCES	does not open eyes		full conjugated eye movements	<i>transient</i> • nystagmus • strabismus • roving eye movements • sunset sign	<i>persistent</i> • nystagmus • strabismus • roving eye movements abnormal pupils
AUDITORY ORIENTATION Infant awake. Wrap infant. Hold rattle 10 - 15 cms from ear.	no reaction	auditory startle; brightens and stills; no true orientation	shifting of eyes, head might turn towards source	prolonged head turn to stimulus; search with eyes; smooth	turns head and eyes towards noise every time; jerky abrupt
VISUAL ORIENTATION Wrap infant, wake up with rattle if needed or rock gently. Note if baby can see and follow red ball (B) or target (T)	does not follow or focus on stimuli B T	stills, focuses, follows briefly to the side but loses stimuli B T	follows horizontally and vertically; no head turn B T	follows horizontally and vertically; turns head B T	follows in a circle B T
ALERTNESS <i>Tested as response to visual stimuli (B or T)</i>	will not respond to stimuli	when awake, looks only briefly	when awake, looks at stimuli but loses them	keeps interest in stimuli	does not tire (hyper-reactive)
IRRITABILITY in response to stimuli	quiet all the time, not irritable to any stimuli	awakes, cries sometimes when handled	cries often when handled	cries always when handled	cries even when not handled
CONSOLABILITY Ease to quiet infant	not crying consoling not needed	cries briefly; consoling not needed	cries; becomes quiet when talked to	cries; needs picking up to console	cries cannot be consoled
CRY	no cry at all	whimpering cry only	cries to stimuli but normal pitch		High pitched cry; often continuous

Fig. 8. Items assessing behavior.

ABNORMAL HAND OR TOE POSTURES		hands open, toes straight most of the time	intermittent fisting or thumb adduction	continuous fisting or thumb adduction; index finger flexion, thumb opposition	continuous big toe extension or flexion of all toes
TREMOR		no tremor or tremor only when crying	tremor only after Moro or occasionally when awake	frequent tremors when awake	continuous tremors
STARTLE	no startle even to sudden noise	no spontaneous startle but react to sudden noise	2-3 spontaneous startles	more than 3 spontaneous startles	continuous startles

Fig. 9. Items assessing abnormal signs.

Other signs, such as abnormal pattern of respiratory muscle activity, inability to suck, and inability to clear secretion, although frequently observed in children with some of the congenital myopathies, can also be a feature of central involvement. In many cases the general physical examination can help to provide

further evidence of neuromuscular involvement.

Contractures, skin dimpling, and poor dermatoglyphic patterns are all indicators of poor fetal movements, are highly suggestive of a neuromuscular disease, and are an indication for detailed neuromuscular investigations.

CNS Involvement

Hypotonia with no evident weakness and normal or increased reflexes will suggest CNS involvement. The advent of cranial ultrasonography and, lately, of magnetic resonance imaging has enabled the direct correlation of clinical findings with the site, size, and evolution of brain

lesions. This allowed us to recognize that certain brain lesions are often associated with specific patterns of neurological signs.

Full-term infants with neonatal encephalopathy. In full-term infants, perinatal events are frequently associated with neonatal encephalopathy. Increased extensor tone in the legs and flexion in the arms or a prevalent extensor tone in the neck and trunk muscles are usually associated with diffuse lesions involving the cortex, the white matter, and the basal ganglia. These findings are even more important considering that these lesions are generally associated with the most severe motor and global outcome [Mercuri et al., 1999].

Other abnormal signs that are also suggestive of these brain lesions are:

- fisting or abnormal posture of the hand or feet in absence of contractures;
- abnormal body movements (tremors, clonus);
- convulsions;
- abnormal eye movements; and
- reduced or absent visual and auditory orientation.
- Sucking abnormalities are not specific, as poor sucking may be present in neuromuscular disorder and severe generalized illness but, if present and associated with other signs of CNS involvement, is strongly suggestive of basal ganglia or brainstem abnormalities.
- Serial neurological examinations will help to follow the evolution of clinical signs in infants with the most common lesions occurring in preterm infants. A good example for these follow.

Intraventricular haemorrhage. Performing serial cranial ultrasound scans and neurological examinations in infants with intraventricular hemorrhage has enabled the identification of three distinct clinical stages (Dubowitz and Dubowitz., 1981; Palmer et al., 1982; Dubowitz et al., 1986):

- Stage 1. Preceding the ultrasound evidence of hemorrhage or at the time of onset, the infant is usually irritable. Hypertonicity (more marked in the arms), excessive motility with tremors and startles may be noted. Tendon reflexes are brisk; the Moro response is exaggerated. Visual and auditory orientations are absent.

- Stage 2 can be seen with established hemorrhage. There is generally poor reactivity. Tone and motility are decreased. One of the most common signs at this stage is a relatively tight popliteal angle, relative to leg tone elicited by traction. Tremors and startles are absent. Visual orientation is absent and auditory responses can be variable.
- Stage 3 is the phase of recovery, usually starting at the end of the first week. Limb tone becomes normal first, including the popliteal angle. Motility improves next. First auditory and then visual orientation recover. Head and trunk control are the last to normalize. During this phase roving eye movements are often noted. In infants who later show abnormal development a number of deviant signs may be noticeable at this stage. The duration of recovery can be quite variable and some children might still show mild tremors and trunk hypotonia even when examined at 40 weeks' gestational age. Interestingly, the severity of the early clinical signs does not necessarily relate to the extent of the hemorrhagic lesion or to later outcome.

Periventricular leukomalacia. Grade I and II leukomalacia are often associated with a normal neurological examination or with only very minor signs. In contrast, cystic lesions are usually associated with deviant signs, which can often be identified in the first weeks of life.

The signs are more severe if the insult occurred during the perinatal or neonatal period and consist of marked hypotonia and lethargy. In contrast, if the insult has occurred some weeks before delivery, during fetal life, the infant might show only mild hypotonia and lethargy at birth. The infants then improve and for a period of a 4–6 weeks they may appear near normal.

Six to 10 weeks after the insult, however, they gradually become more and more irritable but the cry is of normal pitch. They exhibit a very abnormal tone pattern with marked increase of flexor tone in the arms and extensor tone in the legs. Marked neck extensor hypertonia is usually present. Movements are abnormal, often stereotyped or cramped. The finger posture consists of flexion of the thumb and index finger with the other fingers extended. The big toe is

spontaneously dorsiflexed. The Moro reaction is abnormal, consisting of forward extension only, with hardly any abduction or adduction. Frequent tremors and startles may be noted. Visual and auditory functions are normal at this stage. The pattern that can be observed, until this stage, shows few or no differences between the infants with periventricular and subcortical lesions. The clinical evolution is, however, different. While the infants with periventricular lesions become less irritable and develop signs of diplegia but maintain their vision, the infants with subcortical lesions remain irritable, develop severe visual impairment, and frequently infantile spasms and quadriplegia [Dubowitz et al., 1985; Rutherford; 2002].

CAUTIONS AND LIMITATIONS

One of the main limitations of the examination is that it reflects the neurological status of the infant at the time of the examination. Thus any of the factors previously mentioned, such as convulsions, anticonvulsants, or other associated nonneurological systemic illness, can contribute to transient abnormalities of tone and responsiveness. An early neurological examination can therefore be abnormal even in infants who only have rather minor lesions and thus will have a normal outcome. Because of this, the examiner should be cautious and repeat the examination to confirm the persistence of abnormal findings. In full-term infants with neonatal encephalopathy the examination performed after the second week of life is already a reliable predictor of neurological outcome [Mercuri et al., 1999].

The possible effect of ethnic origin on the neurological state of infants has often been regarded as a limiting factor. Although in our experience African children have a slightly better tone compared to Caucasian age-matched controls, in other ethnic groups the variation is small. Optimal infants in Southeast Asia differ little from their Caucasian counterparts. However, in those with various degrees of maternal illness and/or malnutrition, differences are much more marked. The extent to which these are the reflection of the ethnic background and are the main contributing factors remains unsolved [McGready et al., 2000, 2003]. However, in these circumstances the neurological examination is often used to compare groups of infants and thus it remains a useful tool.

STRENGTHS AND BENEFITS

In conclusion, one of the benefits of the examination is that it includes a variety of aspects of neurological function and can therefore provide a quite detailed profile of the neurological status of the infant assessed.

Another benefit is the easy repeatability of the examination. As the examination can be completed in approximately 10 minutes, it can be easily repeated in infants in whom there is a suspicion of neurological abnormalities. This will allow the examiner to not only confirm the persistence of the findings but also to follow their evolution. ■

REFERENCES

- Aiel-Tison C, Grenier A. 1980. Evaluation neurologique du nouveau-né et du nourrisson. Paris: Masson.
- Andre-Thomas A, Chesni Y, Saint Anne Dargassies S. 1960. The neurological examination of the infant. Clinics in Developmental Medicine, Vol. 1. United Kingdom: Heinemann.
- Brazelton TB. 1973. Neonatal behavioural assessment scale. Clinics in Developmental Medicine, Vol. 50. London: Spastics International Medical Publication/W. Heinemann Med. Books.
- Casaer P. 1979. Postural behaviour in newborns infants. Clinics in Developmental Medicine, Vol. 72. United Kingdom: Heinemann.
- Dubowitz L, Dubowitz V, Mercuri E. 1999. The neurological assessment of the preterm and full term infant. Clinics in Developmental Medicine, Vol. 148. London: McKeith Press.
- Dubowitz L, Levene M, Morante A, et al. 1986. Neurological signs in neonatal intraventricular haemorrhage: A correlation with real-time ultrasound. Disabil Rehabil 99:127–133.
- Dubowitz L, Mercuri E, Dubowitz V. 1998. An optimality score for the neurological examination of the term newborn. Disabil Rehabil 133:406–416.
- Dubowitz LM, Bydder GM, Mushin J. 1985. Developmental sequence of periventricular leukomalacia: Correlation of ultrasound, clinical and nuclear magnetic resonance imaging. Arch Dis Child 60:349–355.
- Dubowitz LMS, Dubowitz V. 1981. The neurological assessment of the preterm and full-term newborn infant. Clinics in Developmental Medicine, Vol. 79. United Kingdom: SIMP, Blackwell.
- McGready R, Simpson J, Arunjerda R, et al. 2003. Delayed visual maturation in Karen refugee infants. Ann Trop Paediatr 23:193–204.
- McGready R, Simpson J, Panyavudhikrai S, et al. 2000. Neonatal neurological testing in resource-poor settings. Ann Trop Paediatr 20: 323–336.
- Mercuri E, Guzzetta A, Haataja L, et al. 1999. Neonatal neurological examination in infants with hypoxic ischaemic encephalopathy: Correlation with MRI findings. Neuropediatrics 30:83–89.
- Mercuri E, Guzzetta A, Laroche S, et al. 2003. Neurologic examination of preterm infants at term age: Comparison with term infants. Disabil Rehabil 142:647–655.
- Mercuri E, Heckmatt J, Dubowitz V. 2001. The newborn with neuromuscular disorders. In: Levene MI, Chervenak FA, Whittle M, editors. Fetal and neonatal neurology and neurosurgery, 3rd edition. London: Churchill Livingstone Inc. p 709–726.
- Palmer P, Dubowitz LMS, Levene MI, et al. 1982. Developmental and neurological progress of preterm infants with intraventricular haemorrhage and ventricular dilatation. Arch Dis Child 57:748–752.
- Prechtl HRF. 1977. The neurological examination of the full term newborn infant. Clinics in Developmental Medicine, Vol. 63. United Kingdom: SIMP, Blackwell.
- Prechtl HFR, Einspieler C, Cioni G, et al. 1997. An early marker for neurological deficits after perinatal brain lesions. Lancet 349: 1361–1363.
- Rutherford M. 2002. MRI of the neonatal brain. London: Saunders.
- Saint-Anne Dargassies S. 1977. Neurological development in the full-term and premature neonate. Amsterdam: Elsevier.