

Quality of general movements: A valuable tool for the assessment of neurological integrity in young infants

Alifiani H. Putranti¹, Mijna Hadders-Algra²

Brain development and its significance for neurological diagnosis in infancy

Development of brain is fascinating because of the multitude and complexity of the processes involved in it. It starts with primary neurulation in the third and fourth week of gestation. Primary neurulation refers to formation of the neural tube. This is followed by prosencephalic development in the second and third months of gestation. Development of prosencephalon is considered best in terms of three sequential events, i.e., prosencephalic formation, prosencephalic cleavage, and midline prosencephalic development.¹ This development is followed by proliferation of the brain's total complement of neurons. At a microscopic level, the first process to occur is neuronal proliferation and generation of radial glia. This takes place during the first half of gestation. In addition, cortical neurons will move from their sites of origin in the ventricular and subventricular zones to the loci within central nervous system where they will reside the rest of their life and start to differentiate. Neuronal differentiation and organization processes include establishment and differentiation of sub plate neurons, attainment of proper alignment, orientation and layering of cortical neurons, elaboration of dendritic and axonal ramifications, synapse formation, cell death, selective elimination of neuronal processes, synapses, proliferation and differentiation of glia.¹ Organizational events occur in a peak time period from

approximately the fifth month of gestation to several years after birth. The glia cells take care of axonal myelination. Myelination occurs especially between the second trimester of gestation and end in the first postnatal year. However, it is first completed around 30 years.²

Brain development consists of the creation of components and the elimination of elements. Approximately half of the created neurons die (apoptosis), in particular during mid gestation. Similarly, axons and synapses are eliminated, the later especially between 18 months of age and puberty. The shaping of the nervous system by these regressive phenomena is guided by neural chemical processes and neural activity. The neural elements that fit the environment persist, thus allowing for adaptation of the brain to its own environment.²

This indicates that not only a substantial part of brain development occurs before term age, but also

From the Department of Child Health, Medical School, Diponegoro University, Semarang, Indonesia (AP)¹; From the Department of Neurology-Developmental Neurology, University Medical Center of Groningen, Groningen, the Netherlands (MH)².

Reprint requests to: Alifiani H. Putranti, MD, Department of Child Health, Medical School, Diponegoro University, Kariadi Hospital, Jl. Dr. Soetomo 16-18. Semarang, Indonesia. Telp./Fax 62-24-841 4296. Email: alifiani@yahoo.com

that throughout childhood the brain is in a continuous process of remodeling. The presence of continuous neurobiological changes during childhood has major clinical consequences such as age specific vulnerability of the nervous system with age specific signs and symptoms. Due to the age specific differences, it is difficult to predict nervous system development outcome during early infancy. Age specific neurological assessment is required.^{2,3}

Neurological assessment in early infancy

The reflex and stimulus response notion has dominated the interpretation of the neural function of young nervous system. Sherrington, who was interested in the contact between the afferent and efferent arch in the spinal cord, discovered a contact, which he hypothetically called the synapse. To study the properties of this assumed contact, he did reflex studies in dogs, cats, and monkeys, which performed after decerebration, spinal preparation, and anesthesia. He found that the input output relation between stimulus and reflex was extremely consistent and no longer interfered with fluctuations in neural activity caused by spontaneously generated activity in the nervous system.³

A similar controversial issue is the concept of tonus or muscle tone. It was introduced into neurology of young infants by Andre Thomas. He found cerebellar diseases which deal with tonus changes as an important clinical sign. But the tonus concept is still confusing. Definitions are not standardized and vary greatly, clinical experience indicates the inconsistent character of tonus in young infants and inter observer agreement

is weak. Except for extreme tonus deviations such as floppiness or marked hyper tonus, the prognostic value of tonus deviations is very low.³

A standardized and age specific neurological examination has gained an important position in the neurological assessment of infants and young children. It remains essential to note that in clinical routine examination it rarely tells the examiner what exactly is wrong in young nervous system and why this is so. This is probably due to different concepts and backgrounds of the various examination techniques, which are usually not clearly defined and sometimes not even understood.

In facing this dilemma, it is important to enhance our skills by a new approach to evaluate brain function in young infants. We need an age specific neurological assessment. Prechtel and his co-workers developed a technique, based on the quality of spontaneous motility. In contrast to other techniques, this method is non invasive and does not require expensive equipment. The technique is known as the assessment of the quality of general movements (GMs).⁴ The aim of this paper is to discuss the possibilities of using this new technique for the assessment of neurological integrity in young infants.

Normal general movements

General movements are complex movement patterns involving head, trunk, arms and legs. They have a variable duration and variable movements and trajectories. General movements are present during fetal life and early infancy, they disappear when goal directed movements occur at the age of 3-4 months post term.⁴

Table 1. Age specific characteristics of normal GMs²

GM type	Periods of presence in weeks PMA	Description
Preterm GM	28 week - 36-38 week	Extremely variable movements, including many pelvic tilts and trunk movements
Writhing GM	36-38 wk to 46-52 wk	Something forceful (writhing) has been added to the variable movements. Compared with preterm GMs, writhing GMs seem to be somewhat slower and to show less participation of pelvis and trunk
Fidgety GM	46-52 wk to 54-58 wk	Basic motility consists of a continuous flow of small and elegant movements occurring irregularly all over the body, i.e., head, trunk, and limbs participate to similar extent. The small movements can be superimposed by large and fast movements

General movements are produced by so-called central pattern generator (CPG) networks that can already be observed before the completion of the spinal reflex arch.⁵ That means that general movements can be generated in the absence of afferent information and cannot be related to external stimuli. The activity of the network is located in the spinal cord and brain stem and it is controlled by cortical and subcortical centers. From animal experiments, it is known that spontaneous activity is more easily influenced by compromising conditions of the nervous system than the reflex responses elicited by applied stimuli.⁵ In cases of mild hypoxia or light anesthesia, spontaneous activity decreases while reflexes still can be elicited. These findings indicate a greater sensitivity of spontaneous motor activity to adverse conditions when compared to the reactivity to sensory stimuli.³ Prechtl and co workers stated that general movements during early development play an important role in survival and adaptation. Prechtl also discovered that the quality of GMs can reflect the condition of the nervous system of the fetus and young infant.⁴

General movements show age specific characteristics as shown in **Table 1**. Little is known about the developmental changes of GMs during the first two trimesters of pregnancy. From about 28 weeks until 36 to 38 weeks postmenstrual age (PMA), GMs are characterized by an abundant variation. At 36 to 38 weeks, the preterm GMs change into the forceful writhing GMs. Notably, this transition occurs at the very same age at which fully established behavioral states develop. A second transition in the form of GMs takes place at the age of 6 to 8 weeks post term. At this age, the writhing character of the GMs disappears and is replaced by a continuous stream of tiny and elegant movements that is called fidgety GMs. The finding that the change of writhing GMs into fidgety GMs is much more strongly related to postmenstrual age than to postnatal age, suggests that the developmental changes in the form of normal GMs are mainly based on endogenous maturational processes, leaving a minor role for postnatal experience.² Possibly the neural mechanisms underlying the changes in GMs are maturational changes in the properties of motor neurons, regression of polyneuronal muscle innervations, increasing participation of Renshaw inhibition, and at fidgety age decreasing excitability of motor neurons due to intra- and supraspinal

reorganization.⁶ No relationship has been found between GM development and birth weight.⁷

Abnormal general movements

The principle feature of the assessment of the quality of GMs is the assessment of movement variation and complexity. Complex movements are movements during which the infant actively produces frequent changes in direction of the participating body parts. The changes in movement direction are brought about by continuously varying combination of flexion-extension, abduction-adduction and endo-rotation-exorotation of the participating parts of the body. Variation of movements represents the temporal variation. It means that across time the infant produces continuously new movement patterns.² Thus, the primary parameters of GM-quality evaluate two aspects of movement variation. This fits with the idea that variation is a fundamental feature of function of the healthy young nervous system and that stereotypy is a hallmark of early brain dysfunction.⁸

There are four classifications of general movements: two forms of normal GMs (normal-optimal GMs and normal-suboptimal GMs) and two forms of abnormal GMs (mildly and definitely abnormal general movements) (**Table 2**). Normal-optimal GMs are abundantly variable, fluent and complex, and are relatively rare; only 10% to 20% of three month-old term infants show GMs of such a beautiful quality. The majority of infants show normal-suboptimal movements, which are sufficiently variable and complex but not fluent. Mildly abnormal GMs are insufficiently variable and complex and not fluent and definitely abnormal GMs are virtually devoid of complexity, variation, and fluency. In fact, quality of

Table 2. Classification of the quality of general movements²

	Complexity	Variation	Fluency
Normal-optimal GMs	+++	+++	+
Normal-suboptimal GMs	++	++	-
Mildly abnormal GMs	+	+	-
Definitely abnormal GMs	-	-	-

Complexity and variation: +++ = abundantly present, ++ = sufficiently present, + = present but insufficiently, - = absent. Fluency (the least important aspect of GM assessment): + = present, - = absent movements

movement is a continuum of splendidly complex, variable, and fluent movement, and of very stereotyped movements, such as a repertoire restricted to cramped synchronized movements.² The cramped synchronized movements are characterized by a suddenly occurring en bloc movement, in which trunk and flexed or extended limbs stiffly move in concert.

Significance of the presence of abnormal GMs

Several studies have shown that the quality of GMs reflects the degree of integrity of the nervous system in young infant and that it can predict the neurological outcome to some extent. All studies indicate that especially movement quality at fidgety GM age has predictive power for developmental outcome. The findings of a few studies were discussed. Prechtl⁹ and Einspieler carried out a collaborative study involving five hospitals. They collected data on the quality of fidgety GMs of a highly selective sample of 130 infants and correlated it with neurological outcome at the age of 2 years. Also, information on the neonatal ultrasound scan of the brain was available. Based on ultrasound scan, infants were classified as low risk or at high risk of neurological deficit. The study showed that the quality of GMs at fidgety age had a higher specificity and sensitivity for the prediction of neurological outcome than that of neonatal ultrasound scans. Zuk and Harel,¹⁰ who studied the quality of GMs in 31 infants with asymmetric intrauterine growth retardation and their 31 appropriate for gestational age peers, also found that the quality of movements at fidgety age was most sensitive and specific for the prediction of neurological outcome at 2 years of age. Hadders-Algra¹¹ also reported that the presence of marked abnormal general movements at fidgety GM age indicates a high risk for the development of cerebral palsy, and the presence of normal fidgety GMs is a strong predictor of normal development. More recent studies suggested that the presence of definitely abnormal GMs at fidgety age puts an infant at a high risk for cerebral palsy, and that the presence of mildly abnormal GMs at fidgety age is associated with an increased risk for minor neurological dysfunction, ADHD (Attention Deficit Hyperactivity disorder) and aggressive behaviour at school age.^{12,13}

Hadders-Algra and colleagues¹⁴ demonstrated

that the quality of GMs does not provide a better basis for the prediction of the development of the complex form of minor neurological dysfunction (MND) at toddler or at school age than the traditional neurological signs, such as mild deviation in muscle tone regulation, reflexes and postural control. The assessment of GM quality showed that it had a high sensitivity with moderate specificity to predict neurodevelopmental outcome, whereas the traditional examination paired a rather high specificity with a moderate sensitivity. They concluded that the assessment of the quality of GMs is a complementary tool in the assessment of brain function at early age but does not replace the neurological examination.^{3,15}

Requirements for GM assessment

The evaluation of movement complexity and variation is demanding and requires offline assessment by means of a video recording. Assessment of the movements in real life introduces errors and should be avoided. The video also offers the opportunity of movement replay at high speed, which facilitates the evaluation of movement complexity and variation. Up to term age, the duration of recording is 1 hour. After the term age it is usually better to record movement activity during 10-15 min. Movement elicited by external stimulation should be excluded from analysis.⁴

The optimal state for the assessment of the quality of GMs is active wakefulness, or Prechtl's state 4. In this state, the splendid variation and fluency of normal GMs is expressed best. During other behavioral states normal GM's have features reminiscent of abnormality, implying that a non-optimal state interferes with movement classification. The effects of behavioral state on normal GMs are summarized in **Table 3**. GMs should not be assessed when the subject is crying or is sucking on something.²

Table 3. Effect of behavioral state on normal GMs²

Behavioral state	Complexity and variation	Fluency
Active sleep or REM sleep	Normal	Reduced
Actively awake	Normal	Normal
Crying	Reduced	Reduced
Nonnutritive sucking	Reduced	Normal

REM, rapid eye movement

GM assessment should be done on the infant in supine position. The infant should be offered sufficient space to move and should wear as few clothes as possible. Preterm infants can be assessed excellently in their incubator even whilst being ventilated or having infusion lines. Care should be taken to provide a neutral environmental temperature.⁴

In conclusion, the assessment of the quality of GMs is a sensitive tool to evaluate brain function in young infants. It has a complementary function to the traditional neurological examination. Prediction of developmental outcome based on longitudinal series of GM-assessment is the best. Furthermore, the prediction is based on an assessment at fidgety age.

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