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## Which better predicts later outcome in fullterm infants: quality of general movements or neurological examination?

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### Abstract

The qualitative assessment of general movements (GMs) has been shown to be a better predictor of neurological outcome than the traditional neurological examination in brain-damaged preterm infants. The aim of this study was to compare the results of the two techniques in term infants. Off-line assessment of GMs from videorecordings and neurological examinations were carried out, from birth till about 6 months of postterm age, in a group of 58 term infants, the majority of which were affected by mild to severe hypoxic-ischaemic encephalopathy. The agreement between the two techniques and their predictive power, with respect to the neurological outcome at 2 years, were evaluated for four age groups. The range of agreement between neurological and GM findings was between 78 and 83%. At all ages the results of GM observation correlated highly with the neurological outcome; their sensitivity and specificity with respect to outcome were consistently slightly superior to those of neurological examination. If infants normalize after an initial period of transient abnormalities, GMs normalize earlier than the neurological results. © 1997 Elsevier Science Ireland Ltd.

**Keywords:** General movements; Fullterm infant; Neurological examination; Follow-up; Videorecording; Cranial ultrasound

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## **1. Introduction**

The introduction of sophisticated techniques of exploring the neonatal brain, such as cranial ultrasound, magnetic resonance imaging and magnetic resonance spectroscopy, EEG, evoked potentials and others (see [19] for a review), has supplemented but not replaced the neurological examination of the newborn. The information provided by this examination is still very important for the rapid diagnosis of a neurological disorder in a newborn, for deciding on the need for and type of imaging, electrophysiological or other examinations to be carried out, for formulating a prognosis and for monitoring, by repeated checks, the evolution of the disorder.

Since the first description of concepts and criteria for the neurological examination of newborns by André Thomas and Saint-Anne Dargassies [28], several protocols have been published. However, only two comprehensive methods of neonatal neurological examination have been standardised and validated, those of Precht [21] for term infants and of Dubowitz and Dubowitz [8] for both term and preterm infants. Their diagnostic and prognostic value has been confirmed by numerous studies [3,9,20].

Recently, Precht [23,24] introduced a new approach to the neurological evaluation of newborns and small infants, based on the qualitative observation of spontaneous motility, and particularly of general movements (GM). Studies carried out on fetuses [27], preterm [1,4,13,14,16] and term infants [25], as well as on infants during the first months of life [10,26] have shown that the results of this assessment correlate very well both with the presence of brain lesions, detected by neuroimaging techniques, and with the neurological outcome. The prognostic value of this new, non-invasive, low-cost, non-time-consuming technique increases considerably when the results of repeated evaluations and the type of GM abnormality are considered.

The findings obtained by means of GM observation have recently been compared with those of traditional neurological examination in a large group of preterm infants [4], serially tested from birth until about 6 months of corrected age. This study has indicated that the correlation between the findings of the two techniques is low during the preterm and term period, but subsequently becomes higher. At all ages, but particularly before the second month of corrected age, GM observation is a better predictor of neurological outcome at 2 years.

A previous study, carried out on a group of term infants affected by mild to severe hypoxic-ischaemic encephalopathy [25], seemed to indicate a slightly higher prognostic value of GM observation in the first 2 weeks after birth and of neurological examination at about 4–6 months. However, for term infants a systematic comparison of the results provided by the two techniques at the different ages and in a large population of subjects has not, till now, been available.

The aim of this study was to compare the results of a series of GM observations and traditional neurological examinations carried out simultaneously on a group of term infants with various neurological conditions. The specific questions we addressed, similar to those previously investigated on preterm infants, were the following:

1. How concordant are the findings of GM observation and neurological examination, carried out at the same age, from the term period to the first post-term months?
2. What is the validity of the two methods of assessment in predicting the neurological outcome at 2 years?
3. What is the predictive power of individual developmental trajectories of GM observation and of neurological assessment?
4. Is there any relationship between specific GM and neurological abnormalities?
5. What is the relationship between US findings, developmental trajectories, and neurological outcome?

## 2. Subjects and methods

### 2.1. Subjects

For the purpose of the present research we selected, from a group of about 180 cases enrolled from 1985 in a prospective collaborative study of GM observation by the Universities of Modena and Pisa, all infants fulfilling the following criteria:

- gestational age  $\geq 37$  completed weeks;
- available results of serial US scans, with 5 and 7.5 MHz heads;
- repeated videorecordings and neurological examinations until about 65 weeks of PMA;
- neurological follow-up until 2 years of corrected age.

All cases with inherited metabolic disorders, chromosomal defects or other recognisable malformations of the brain or other organs were excluded; we also excluded the infants with missing GM observations or neurological examinations at more than one key age of observation.

The final sample is shown in Table 1. It consisted of 58 infants (34 male and 24 female); their gestational age ranged from 37 to 41 weeks (mean 39, SD 1) and birth weight from 1870 to 4350 g (mean 3166, SD 540); five of them were SGA, i.e. with birth weight below 5th percentile. Thirty-eight of the infants were affected by post-asphyxial encephalopathy, documented by a history of fetal distress and neonatal neurological signs; according to Levene's three point grading system [18], 16 infants had a severe encephalopathy and the other 22 a mild one. Six infants showed other neonatal syndromes (IUGR in three cases, neonatal cryptogenetic convulsions in one, septicaemia in another one and a brain parenchymal haemorrhage in the last one). Fourteen cases had uneventful obstetrical and neonatal histories. Partial results of some of these cases were included in a previous report [25].

Serial US scans were carried out until discharge from the NICU; brain haemorrhage was classified according to US grading of Levene and coworkers [17] and leukomalacia according to de Vries et al. [6]. In cases of multiple lesions, the infants were classified according to the most severe one. Thirty-five subjects (60.3%) had

Table 1  
Main clinical findings of the study group of 58 term infants

Gestational age (weeks)	Mean: 39	SD: 1	Range: 37–41
Birth weight (g)	Mean: 3166	SD: 540	Range: 1870–4350
Neonatal diagnosis	Normal: 14	Mild HIE: 22 Severe HIE: 16	Other: 6
US findings	Normal: 35	IVH I b: 1 IVH III: 2	PVL I: 12 PVL II: 3 PVL III–IV: 5
Neurological outcome at 2 years	Normal: 40	Mildly abnormal: 2	Severely abnormal: 16

normal US, 13 (22.4%) showed mild brain US abnormalities, i.e. intraventricular haemorrhage grade I–II or prolonged flare, and 10 (17.3%) severe ones, i.e. intraparenchymal haemorrhage (IVH grade III) or cystic leukomalacia (PVL grade II–IV).

Sixteen infants (27.5%) had a severely abnormal outcome: 14 showed a cerebral palsy (5 tetraplegia, 3 diplegia, 4 hemiplegia and 2 dyskinesia), 2 showed a severe mental deficit; 2 other infants (3.5%) had a mild developmental retardation.

The study was approved by the Scientific Research Committees of the Stella Maris Foundation and of the Italian Ministry of Health.

## 2.2. Observation of general movements

Serial videorecordings, each lasting 1 h, were made from the first days of life according to the standard procedure of Prechtl's method for GM observation, as described in detail in several papers [4,13,23,25]. The video-camera was positioned approximately one meter above the incubator or the warmer, at an angle of 45°. The subjects were recorded during interfeeding time, in supine position, naked or in a nappy.

After the infants had been discharged from the hospital, the videorecordings were performed in the outpatient clinic, usually at intervals of 3–4 weeks, to, at most, 65 weeks of postmenstrual age (PMA); the infants were observed partially dressed in supine, during periods of active wakefulness, for about 15 min. Three to four GMs each lasting 20–30 s or longer and excluding crying, fussing or sucking periods, were selected for each particular age. The observation was discarded if no GMs corresponding to the previous criteria were found.

The GMs were analysed, in accordance with the previous studies in two ways:

a) a global judgement of normal or abnormal quality of GMs based on Gestalt perception;

b) an assessment of separate aspects of the GMs, such as speed, amplitude, movement character, sequencing, spatial sectors, fluency and elegance, onset-offset

and subtle distal movements, and their combination into different types of abnormality (see Section 2.4).

The quality of the GMs was assessed blindly by one of us (H.F.R.P.), unaware of the clinical history of the infants, and re-tested by a second scorer (G.C.); the inter-observer agreement, using Kappa [5], was 0.87.

After the GMs have disappeared (at about 56–60 weeks PMA) the quality of spontaneous motility was judged (key age 57–65 weeks). This judgement included kicking of the legs, leg lift, hand-knee contact, manipulation, reaching and touching objects.

### 2.3. Neurological examination and follow-up until 2 years of age

In the first days of life, repeated neurological examinations were carried out using the Prechtl protocol [21]. Neurological development during the first 6 months post-term was assessed on the same occasion as the recordings of spontaneous motility were made, by means of the Amiel-Tison and Grenier examination [2] or using Touwen's criteria [29].

The neurological outcome at 24 months was examined by extended and age-related items of the above indicated neurological examinations and by the Griffiths Scales in the English version [15]. It was classified as normal (no neurological signs,  $DQ > 85$ ), mildly abnormal (when neurological signs were observable, but not cerebral palsy, or  $DQ$  was between 84 and 50), or severely abnormal (cerebral palsy or  $DQ < 50$ ).

### 2.4. Comparison between GM observation and neurological examination

The presence of two main abnormal GM qualities, reported in previous papers [4,13,25,26], was systematically investigated:

1. *poor repertoire GMs*: the components of each sequence of successive movement were monotonous and the movements of the different body parts did not occur in the complex sequence observable in normal GMs;
2. *cramped-synchronized GMs*: they looked rigid, had not the normal smooth writhing character, and all limb and trunk muscles contracted and relaxed almost simultaneously.

The results of Prechtl's neurological examination were classified according to the list of categories (syndromes of abnormal posture, motility, motor system, symmetry, reactivity) indicated in the summary form [21]. Delay of neurological development and/or specific signs of abnormality during the postterm period were noted according to protocol norms [2,29].

GM observation and neurological examination were scored as normal when none of the abnormalities indicated above were found, and abnormal when at least one of them was present. A judgement of the severity of neurological abnormalities (e.g. mild or severe hypertonia) was made.

**Case:** T.A. (sev.HIE)    **GA (wks):** 41    **BW (g):** 4050

**US:** PVL I

**Outcome:** normal

	<i>term period</i>	<i>post-term period</i>			
<b>PMA (wks)</b>	42	44	49	51	57
<b>GM obs.</b>	normal	normal	normal	normal	normal
<b>Neurol. exam.</b>	mild hypot.	normal	normal	normal	normal

Fig. 1. Trajectories of GM and neurological characteristics during term and post-term periods of a fullterm infant with severe hypoxic-ischaemic encephalopathy. GM observations and neurological examinations were consistently normal, except for a mild hypotonia at 42 weeks. Outcome was normal.

The results of repeated neurological and GM assessment were displayed on the time axis, thus depicting individual developmental trajectories (see Fig. 1–Fig. 5).

As in the previous study on preterm infants, longitudinal data were split into “key-age” periods, namely term age (38–42 weeks), 43–47, 48–56 and 57–65 weeks of PMA.

The agreement between the two examinations for normal or abnormal results was

**Case:** C.A. (sev.HIE)    **GA (wks):** 40    **BW (g):** 3220

**US:** PVL IV

**Outcome:** tetraplegia

	<i>term period</i>	<i>post-term period</i>			
<b>PMA (wks)</b>	42	45	49	53	57
<b>GM obs.</b>	cramped synchr.	cramped synchr.	cramped synchr.	cramped synchr.	cramped synchr.
<b>Neurol. exam.</b>	hypertonia hyperex.	hypertonia	hypertonia	hypertonia	hypertonia

Fig. 2. Trajectories of GM and neurological characteristics during term and post-term periods of a fullterm infant with severe hypoxic-ischaemic encephalopathy. GM observations and neurological examinations were consistently abnormal. Outcome was spastic tetraplegia and severe mental retardation.

**Case:** B.L. (sev.HIE)    **GA (wks):** 39    **BW (g):** 2600

**US:** PVL II, bright thalami    **Outcome:** normal

	<i>term period</i>		<i>post-term period</i>		
<b>PMA (wks)</b>	41	43	49	52	61
<b>GM obs.</b>	poor repertoire	poor repertoire	normal	normal	normal spontaneous motility
<b>Neurol. exam.</b>	hypotonia	limb hypert. trunk hypot.	tremors	hypertonia	normal

Fig. 3. Trajectories of GM and neurological characteristics during term and post-term periods of a fullterm infant with severe hypoxic-ischaemic encephalopathy. GM observation normalized earlier than neurological examination. Outcome was normal.

checked. If, for a single subject, more than one judgement per age period was available, the averaged agreement value between the two techniques was taken. However, when the results were compared with the neurological outcome, the first observation per age period was used.

**Case:** L.S. (sev.HIE)    **GA (wks):** 38    **BW (g):** 2250

**US:** PVL II (R>L)    **Outcome:** mild L hemiplegia

	<i>term period</i>		<i>post-term period</i>		
<b>PMA (wks)</b>	42	43	46	50	60
<b>GM obs.</b>	poor repertoire	poor repertoire	poor repertoire	poor repertoire	normal spontaneous motility
<b>Neurol. exam.</b>	hypotonia	mild hypotonia	hypotonia	hypotonia	asym.

Fig. 4. Trajectories of GM and neurological characteristics during term and post-term periods of a fullterm infant with severe hypoxic-ischaemic encephalopathy. Spontaneous motility was normal at 60 weeks, whereas neurological examination showed an asymmetry of muscle tone. Outcome was mild left hemiplegia.

**Case:** A.D. (sev.HIE)    **GA (wks):** 40    **BW (g):** 2850

**US:** PVL II

**Outcome:** dyskinetic CP

	<i>term period</i>	<i>post-term period</i>		
<b>PMA (wks)</b>	41	52	57	65
<b>GM obs.</b>	poor repertoire	poor repertoire	poor repertoire	poor repertoire motility
<b>Neurol. exam.</b>	hypotonia	normal	normal	dyskinesia

Fig. 5. Trajectories of GM and neurological characteristics during term and post-term periods of a fullterm infant with severe hypoxic-ischaemic encephalopathy. GM observations were consistently abnormal, whereas neurological examination was normal at 57 and 65 weeks. Outcome was dyskinetic cerebral palsy.

### 3. Results

#### 3.1. Concordance of GM observation and neurological examination

The percentage of subjects showing abnormalities at GM observation or neurological assessment at the various ages are shown in Table 2. The number of cases varies slightly in different age groups, as some observations were missing or were excluded for one of the reasons mentioned in the previous paragraphs.

The incidence of neurological abnormalities was higher than that of GM abnormalities at most ages; for both techniques abnormality incidence tended to decrease.

Table 2  
Distribution of neurological and GM findings and their agreement at the various age periods

		Term age	Post-term period		
Postmenstrual age (wks)		38–42	43–47	48–56	57–65
No. of cases		51	45	58	54
GM observation					Spontaneous motility
Normal	%	41.2	55.6	58.6	62.9
Abnormal	%	58.8	44.4	41.4	37.1
Neurological exam.					
Normal	%	43.1	44.4	55.2	57.4
Abnormal	%	56.9	55.6	44.8	42.6
Agreement	%	82.3	77.8	82.7	83.3



from term age to 65 weeks of PMA. Often subjects resulted normal or abnormal at both techniques of assessment (Fig. 1 and Fig. 2); the overall percentage of agreement of the results was 81.5%, varying from 78 to 83% without any age-related trend. At term age, discordant results were equally due to subjects with abnormal GMs and normal neurological examinations and vice versa. After term age, the discrepancies were mainly accounted for by some infants with mild neurological abnormalities who had normal GMs (Fig. 3 and Fig. 4).

### 3.2. GM observation, neurological examination and outcome

The predictive value of the two methods was investigated by computing for all ages the sensitivity and the specificity of their results (Table 3), in relation to the abnormality or normality of the outcome.

GM observation and neurological examination showed good sensitivity values, slightly better for the former at all key ages, with the exception of 57–65 week, when GMs have disappeared and the judgement was based on spontaneous motility of the infants. The neurological examination scored 94.1%, against 82.3% of spontaneous motility. At that age, two subjects with a mild hemiplegia as outcome showed mild neurological abnormalities but normal spontaneous motility (Fig. 4). Normal motility was consistently observed in another case of mild developmental retardation. One infant who developed a dyskinetic cerebral palsy (Fig. 5) and three others with a mild hemiplegia were scored as neurologically normal in their first weeks.

Specificity was low for both techniques at term age (58.8%), because some subjects with poor repertoire GMs or mild neurological abnormalities at that age were normal at 2 years. Already at 43 weeks the specificity of GM observation was high (85.7%), whereas neurological examination obtained similarly high values of specificity only after 57 weeks of PMA. According to these data normalization of transient disorders seems to occur earlier for GMs (Fig. 1 and Fig. 3).

Table 3

Predictive indexes of GM observation and neurological examination, with respect to neurological outcome at 2 years

		Term age	Post-term period		
Postmenstrual age (wks)		38–42	43–47	48–56	57–65
No. of cases		51	45	58	54
GM observation					Spontaneous motility
Sensitivity	%	94.1	94.1	94.4	82.3
Specificity	%	58.8	85.7	82.5	83.8
Neurological exam.					
Sensitivity	%	88.2	88.2	88.9	94.1
Specificity	%	58.8	67.8	72.5	81.1

3.3. Predictive value of GM and neurological trajectories

Different patterns of developmental course of GM and neurological findings (trajectories) could be identified, according to the severity and persistence of the abnormalities. The relationship between these trajectories and the neurological outcome is shown in Fig. 6.

The presence of consistent GM abnormalities (poor repertoire or cramped-synchronized) was a strong predictor of an unfavourable outcome (sensitivity 88.9%), whereas consistently normal or transiently abnormal GMs generally predict normal development (specificity 95%). The exceptions were the two cases, already mentioned, with mild hemiplegia despite normalization of GMs (Fig. 4), another case with consistently normal GM and mild developmental retardation, and two others with consistent poor repertoire but normal outcome at 2 years.

The presence of consistent neurological abnormalities had an identical specificity (95%), but a lower sensitivity (72.2%). Five infants with inconsistent abnormalities of the neurological examination before 7 weeks showed severe or mild abnormalities at 2 years. Conversely, two infants with mild but consistent neurological abnormalities had a normal outcome.

3.4. Ultrasound findings and developmental profiles

High sensitivity and specificity values for the outcome were found for US abnormalities, i.e. 88.8% and 82.5% respectively. Discrepancies were due to 7 out of the 13 subjects with mild US abnormalities (mainly prolonged flare) who had a favourable outcome. Five of these seven cases showed consistently normal GMs, and the other two transient abnormalities; three of them had normal results at the neurological examination and, the other four, transient abnormalities. The two cases with abnormal outcome despite normal cranial US had consistent GM abnormalities, and one of them also had consistently abnormal neurological findings.

	<i>normal</i>	<i>transient poor repertoire</i>	<i>transient cramped-synchr.</i>	<i>consistent poor repertoire</i>	<i>consistent cramped-synchr.</i>
<b>GM observation</b>	○○○○○○○ ○○○○○○○ ○○○○○○○ ○○	○○○○○○○ ○○○○○○○ ○○○○○○○	○○○○●	○○○○○○○● ●	●●●●●●●● ●●
<b>neurological examination</b>	○○○○○○○ ○○○○○○○ ○○○○	○○○○○○○ ○○○○○○○ ○○○○●●●●	○○○○●	○○○○●	●●●●●●●● ●●●●
	<i>normal</i>	<i>transient mild abnormality</i>	<i>transient severe abnormality</i>	<i>consistent mild abnormality</i>	<i>consistent severe abnormality</i>

○ normal outcome at 2 years; ⊙ mildly abnormal; ● severely abnormal

Fig. 6. Correlation between GM and neurological trajectories and neurological outcome.

### 3.5. Relationship between types of GM and neurological abnormalities

A positive correlation between cramped-synchronized GMs and presence of hypertonia was found (Fig. 2). Seven of the nine infants with consistent cramped-synchronized character showed mild or severe hypertonia at the neurological examination. In five of them, cramped-synchronized GMs were observed before the onset of hypertonia, whereas these two motor features appeared simultaneously in the other two cases. Transient cramped-synchronized character was never associated with hypertonia. No other correlation between GM and neurologically abnormal features was observed.

## 4. Discussion

The diagnostic and prognostic value of GM observation, already reported for preterm infants [1,4,13,14,16,24,26] and in a smaller group of term infants with hypoxic-ischaemic encephalopathy [25] has been confirmed by the results of this study.

The comparison of the results obtained by GM observation and traditional neurological assessment at different ages has indicated quite a high overall agreement (81.5%) between the two techniques, with no substantial variation from term age to the sixth month. A lower agreement between assessment of quality of GM and neurological examination has recently been reported by Hadders-Algra et al. [16]. However, the number of cases included in that study was quite small (16 cases), no distinction between term and preterm infants was made for the comparison, and a more elaborate classification of GM abnormalities was applied with distinguishing more different categories. The poor repertoire GMs were called 'mild abnormalities'. In our study we could show that consistent poor repertoire pattern has in more than half of the cases an outcome of cerebral palsy (see Fig. 6). Hence, the term 'mild abnormality' is mistaken and the refinement of the classification is not an improvement.

In a group of high-risk preterm infants, tested with a methodology identical to that applied in the present study, a similar overall agreement was reported [4], but with strong age-related differences. GM observation and neurological examination quite often showed discordant results during the preterm period and at term age. These findings might be due to the difficulty of performing a neurological examination with very young and fragile infants; moreover these subjects frequently show mild neurological abnormalities due to transient systemic complications. At term age transiently normal neurological examinations, with abnormal GMs, were found in preterm infants who later developed a cerebral palsy. A transient period of normalization between declining hypotonia and increasing hypertonia, sometimes occurring at that age, has previously been reported [7].

Not surprisingly, in preterm infants the two techniques showed substantial differences in their prognostic value for the neurological outcome at 2 years. At all ages, but in particular at preterm and term age, GM observation had better sensitivity

and specificity values than neurological examination. These findings can be accounted for by the reasons reported in the previous paragraph. Specificity was always inferior to sensitivity for both techniques [4].

The results of the present study indicate a more similar prognostic value of the two methods of assessment in term infants. However, once again GM observation had higher sensitivity and specificity values at almost all ages. The specificity of both techniques was lower than the sensitivity at term age, but higher than in preterm infants evaluated at the same age.

The neurological examination gave a higher number of false positive results for the outcome; it seems that this method is more sensitive to mild abnormalities of transient neurological functions. The false negative observations were also more numerous with neurological examination than with GM evaluation: three infants who later developed a mild hemiplegia and one with a dyskinetic cerebral palsy were described as neurologically normal in their first weeks. One case of mild developmental retardation was constantly judged as having normal GMs; this occurred also in the late observations of two of the cases with a mild hemiplegia.

The differences between the results of the present study, in comparison with those reported in preterm infants, might be also accounted for by the different features of brain lesions occurring in fullterm infants.

Because of its characteristics (non invasive, easy and quickly to perform etc.) GM observation is ideal for serial assessments. The results shown in this study have confirmed the importance of observing the developmental changes of motor features in high-risk cases. As for preterm infants, the presence or absence of consistent GM abnormalities, and in particular of a cramped-synchronized character, allows a fairly precise prediction of the outcome at 2 years. The predictive value of developmental profiles was much higher than that of a single GM assessment, especially when carried out before the second month of life. At around that age a major transformation of several neural functions occurs, including changes of GM features from writhing to fidgety quality [22]. A recent study has shown that the absence or presence of normal fidgety GMs are strong predictors for the neurological outcome [25].

This technique seems to be particularly useful in association with neuroimaging examination. Earlier reports indicated that in fullterm infants with hypoxic-ischaemic encephalopathy the value of cranial ultrasound for detecting intracranial abnormalities and predicting outcome was lower than in preterm infants [12]. Confirming the results of more recent publications [11], ultrasound findings in the present study showed good sensitivity and specificity values with respect to outcome. The use of modern US equipment and transducers might account for these better results. However, minor US abnormalities might be equally related to favourable or unfavourable outcomes: for these cases, observation of GM quality, rather than traditional neurological examination, was of crucial importance in predicting the final outcome.

In conclusion, the results of this study have confirmed the importance of GM observation in the neurological assessment of fullterm newborns and young infants at risk for brain lesions and later neurological impairment. In comparison with traditional neurological examination, the results obtained by this technique, which is less invasive and time consuming, are similar and often more closely correlated with the outcome.

However, there are limitations to this method. It cannot be applied to comatose infants or with severe depression of the nervous system, who hardly move (e.g. subjects with severe hypoxic-ischaemic encephalopathy in their first hours of life). In these cases, neuroimaging, electrophysiological techniques, and some subsets of traditional clinical assessment have a prominent role in detecting the severity of brain impairment and indicating the prognosis [11,19,25]. Moreover, traditional neurological assessment provides a more comprehensive picture of the various neural subsystems, some of which (e.g. the oculo-motor system or peripheral nerves) cannot be tested by GM observation.

Finally, further studies are still needed to assess the value of this technique for the prognosis of these high-risk infants at school age and later.

## **5. Notation**

asym: asymmetry

BW: birth weight

CP: cerebral palsy

DQ: developmental quotient

exam: examination

GA: gestational age

GM: general movements

HIE: hypoxic-ischaemic encephalopathy

IUGR: intrauterine growth retardation

IVH: intraventricular haemorrhage graded according to Levene et al. [17]

L: left

MRI: magnetic resonance imaging

neuro!: neurological

NICU: neonatal intensive care unit

obs: observation

PMA: postmenstrual age

PVL: periventricular leukomalacia graded according to de Vries et al. [6]

R: right

SD: standard deviation

SGA: small for gestational age

synchr: synchronized

US: ultrasound

wks: weeks

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## References

- [1] Albers S, Jorch G. Prognostic significance of spontaneous motility in very immature preterm infants under intensive care treatment. *Biol Neonate* 1994;66:182–7.
- [2] Amiel-Tison C, Grenier A. *Neurologic evaluation of the newborn and the infant*. New York: Masson, 1983.
- [3] Bierman-van Eendenburg MEC, Jurgens-van der Zee AD, Olinga AA, Huisjes HJ, Touwen L BC. Predictive value of neonatal neurological examination: a follow-up study at 18 months. *Dev Med Child Neur* 1981;23:296–305.
- [4] Cohen J. A coefficient of agreement for nominal scales. *Educ Psychol Meas* 1960;20:37–46.
- [5] Cioni G, Ferrari F, Einspieler C, Paolicelli PB, Barbani MT, Prechtl HFR. Comparison between observation of spontaneous movements and neurological examination in preterm infants. *J Pediatr* 1997;130:704–11.
- [6] de Vries LS, Eken P, Dubowitz LMS. The spectrum of leukomalacia using cranial ultrasound. *Behav Brain Res* 1992;49:1–6.
- [7] Dubowitz LMS. Clinical assessment of infant nervous system. In: Levene MI, Bennett MJ, Punt J, editors. *Fetal and Neonatal Neurology and Neurosurgery*, 1st ed. Edinburgh: Churchill Livingstone, 1988:33–40.
- [8] Dubowitz LMS, Dubowitz V. The neurological assessment of the preterm and fullterm newborn infant. *CDM vol. 79*. London: Heinemann, 1981.
- [9] Dubowitz L, Dubowitz V, Palmer P, Miller G, Fawer C, Levene M. Correlation of neurological assessment in the premature newborn infant with outcome at 1 year. *J Paediatr* 1984;105:452–6.
- [10] Einspieler C. Abnormal spontaneous movements in infants with repeated sleep apnoeas. *Early Hum Dev* 1994;36:31–48.
- [11] Eken P, Toet MC, Groenendaal F, de Vries LS. Predictive value of early neuroimaging, pulsed Doppler, and neurophysiology in full term infants with hypoxic-ischaemic encephalopathy. *Arch. Dis Child* 1995;73:F75–80.
- [12] Fawer CL, Calame A. Ultrasound. In: Haddad J, Christmann D, Messer J, editors. *Imaging Techniques of the CNS of the Neonates*. Berlin: Springer-Verlag, 1991:81–107.
- [13] Ferrari F, Cioni G, Prechtl HFR. Qualitative changes of general movements in preterm infants with brain lesions. *Early Hum Dev* 1990;23:193–231.
- [14] Geerdink JJ, Hopkins B. Qualitative changes in general movements and their prognostic values in preterm infants. *Eur J Paediatr* 1993;152:362–7.
- [15] Griffiths R. *The ability of babies*. London: University Press, 1954.
- [16] Hadders-Algra M, Klip-van den Nieuwendijk AWJ, Martijn A, van Eykern LA. Assessment of general movements: towards a better understanding of a sensitive method to evaluate brain function in young infants. *Dev Med Child Neur* 1997;39:89–99.
- [17] Levene MI, Fawer CL, Lamont CF. Risk factors in the development of intraventricular haemorrhage in the preterm newborn. *Arch Dis Child* 1982;57:410–7.
- [18] Levene MI, Kornberg J, Williams THC. The incidence and severity of post-asphyxial encephalopathy in full-term infants. *Early Hum Dev* 1985;11:21–6.
- [19] Mercuri E, Dubowitz L. The prognosis of neonatal neurological abnormalities. *Bailliere's Clin Paediatr* 1996;4:393–409.
- [20] Molteni C, Grosz P, Wallace P, Jones M. Neurological examination of the preterm and full-term infant at risk for developmental disabilities using the Dubowitz neurological assessment. *Early Hum Dev* 1995;41:167–76.
- [21] Prechtl HFR. *The neurological examination of the full-term newborn infant*. 2nd ed. Revised and enlarged. *CDM vol.63*. London: Heinemann, 1977.

- [22] Prechtl HFR. Continuity and change in early neural development. In: Prechtl HFR, editor. *Continuity of Neural Functions from Prenatal to Postnatal Life*, CDM vol. 94. Oxford: Blackwell, 1984: 1–15.
- [23] Prechtl HFR. Qualitative changes of spontaneous movements in fetus and preterm infants are a marker of neurological dysfunction. *Early Hum Dev* 1990;23:151–8.
- [24] Prechtl HFR, Nolte R. Motor behaviour of preterm infants. In: Prechtl HFR, editor. *Continuity of Neural Functions from Prenatal to Postnatal Life*, CDM vol. 94. Oxford: Blackwell, 1984:79–92.
- [25] Prechtl HFR, Ferrari F, Cioni G. Predictive value of general movements in asphyxiated fullterm infants. *Early Hum Dev* 1993;35:91–120.
- [26] Prechtl HFR, Einspieler C, Cioni G, Bos AF, Ferrari F, Sontheimer D. An early marker for neurological deficits after perinatal brain lesions. *Lancet* 1997;349:1361–3.
- [27] Sival DA, Visser GHA, Prechtl HFR. The effect of intrauterine growth retardation on the quality of general movements in the human fetus. *Early Hum Dev* 1992;28:119–32.
- [28] Thomas A, Saint-Anne Dargassies S. *Etudes neurologique sur le nouveau-né et le jeune nourrisson*. Paris: Masson, 1952.
- [29] Touwen BCL. *Neurological development in infancy*. CDM vol. 58. London: Heinemann, 1976.