Application of a Scorable Neurological Examination to Near-Term Infants: Longitudinal Data

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- Hammersmith Infant Neurological Examination
- preterm infants
- outcome

Abstract

The aim of this study was to follow the evolution of neurological findings in a cohort of near-term infants born between 35 and 37 weeks. A total of 448 infants born between 35 and 36.9 weeks gestational age with normal cranial ultrasonograms or only minor abnormalities, were studied using the Hammersmith Infant Neurological Examination, at 6, 9 and 12 months (corrected for prematurity). Our results showed that while some items such as cranial nerve and movements showed minimal changes over time, other items mainly related to "tone", "posture" and "reflexes" showed progressive maturation. There was no significant difference between the infants born at 35 and 36 weeks gestation. When compared to term infants assessed at the same age intervals, our cohort showed a wider variability of scores. Mean and 10th percentile for global scores were lower than those reported for term infants suggesting that when assessing infants born at 35 and 36 weeks the optimality scores used for infants born full-term should not be used as normative data. Our results, providing longitudinal data in near-term infants without brain lesions, can be used as a reference in both clinical and research setting to monitor early neurological signs in those children.

Introduction

In the early 1980s, a method for the neurological assessment of preterm and term newborn infants was developed by Dubowitz and co-workers [3]. More recently, the same authors developed a neurological examination based on the same principles to be used during the first two years of life, the Hammersmith Infant Neurological Examination (HINE) [4,8]. The HINE was originally validated in a population of healthy term infants assessed at 12 and 18 months, and an optimality score was developed based on the frequency distribution of individual items and of the global scores [8]. The application of the global optimality score to full-term infants with brain lesions resulted in an accurate prediction of motor outcome at 2 and 4 years [9,15]. All infants with optimal scores at 9 months were able to walk independently by the age of 2 years, while the 81% of those with suboptimal scores developed cerebral palsy in that patient group [9]. The same group has also used the HINE optimality score in a population of preterm infants born before 31 weeks gestation [5]. There was a clear correlation between scores and outcome with scores above 64 always associated with independent walking at 2 years. Interestingly, despite age correction for preterm birth, normal motor outcome was found in 48% of infants with scores that were considered as sub-optimal (<73) according to the normative data collected in low-risk full-term infants [8], suggesting a wider variability of neurological findings in preterm infants. Less has been reported for infants born at more advanced gestational age (GA), such as those born between 35 and 37 weeks. As previous studies have reported a marked difference in scores between preterm and full-term infants [5], we wished to investigate the profile of neurological findings in such cohort born only a few weeks before term.

We systematically applied the HINE at 6, 9 and 12 corrected months in a large population of near-term infants selected on the basis of a normal neurodevelopment at 24 months. Specific aims of our study were i) to establish the range and frequency distribution of HINE neurological scores in low-risk near-term infants throughout the first year of life, and ii) to expand the optimality score developed for full-term infants,

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identifying the 10th percentile cut-off score as a reference value for our near term infants.

Patients and Methods

The infants reported in this study were part of a cohort of 1853 newborns consecutively enrolled in a follow-up research programme including all infants admitted at the Neonatal Unit of the University Hospital of Catania, between January 2000 and December 2004. As part of our research program, all infants born before 37 weeks GA have serial ultrasounds (US) in the neonatal period and are enrolled in a follow-up programme until the age of 2 years. Cranial ultrasound scans were performed during the first days after birth while inpatients and repeated at 14 days and at term age at scheduled follow-up appointments. The follow-up included the HINE at 6, 9 and 12 months of corrected age (CA), and a neurodevelopmental assessment at 2 years CA including a structured neurological examination [16] and the Clinical Adaptive Test/Clinical, Linguistic and Auditory Milestone Scale (CAT-CLAMS) [2]. The CAT/CLAMS is used to assess an infant's development from 1 to 36 months and measures receptive and expressive language development and visual-motor problem-solving skills. The test takes only 10 to 15 minutes to administer and when compared to the Bayley Scales of Infant Development II, the correlation coefficients have been reported to be as high as 95%, making this tool a valid alternative to more detailed and time-consuming neurodevelopmental scales for large follow-up programmes [11, 14].

For the purpose of this study, infants were selected from the whole population according to the following criteria: i) GA between 35 and 36.9 weeks, ii) normal cranial US or transient flares (lasting less than 2 weeks) or germinal layer haemorrhages grade 1 (IVH 1) according to Volpe [18], iii) normal outcome at 2 years CA defined as a normal neurological examination and a CAT-CLAMS quotient above 80. All infants small for gestational age (weight below the 10th percentile) or with congenital malformations were excluded. Parental written permission was obtained in all cases, and the study was approved by the Ethical Committee of our Institution.

Clinical examination

All infants were assessed using the HINE at 6, 9,12 months CA. This includes 26 items, exploring five areas: cranial nerve, posture, movements, tone and reflexes. The options for each item are subdivided into four columns and the examiner marks each item by circling the relevant response. A score of 3 is given to the findings of column 1, a score of 2 for column 2, a score of 1 for column three and a score of 0 for column 4. The examination gives a sub-score for each subsection and an overall optimality score, ranging from a minimum of 0 to a maximum of 78. All neurological examinations were performed by one of two examiners (DMMR, MCo).

The inter-observer reliability of the method has already been published [8], but we performed further reliability inter-observer assessments. The first one was performed in 150 infants by 2 examiners (DMMR and MS). The maximum difference between observers was always 1 column in individual items, especially in posture and tone subsections. A maximum of 3 items differed in the whole assessment. The inter-observer correlation coefficient was above 0.90. A further session was performed on thirty children between the two examiners who performed the present study with similar results (DMMR, MCo).

All examinations were performed when infants were in the most appropriate behavioural state (state 4 according to Brazelton) [1].

Table 1 Mean and standard deviations (SD) for global scores and sub-scores in infants grouped according to gestational age

		35 (206) Mean (SD)	36 (242) Mean (SD)
6 months	**global score**	**67.8 (2.5)ns**	**67.5 (3.0)**
	cranial nerves	14.6 (0.6)ns	14.6 (0.6)
	posture	15.6 (1.4)ns	15.4 (1.5)
	movements	5.8 (0.4)ns	5.8 (0.5)
	tone	20.8 (1.2)ns	20.7 (1.5)
	reflexes	11.2 (2.1)ns	11.0 (2.2)
9 months	**global score**	**71.6 (2.2)ns**	**71.1 (2.9)**
	cranial nerves	14.6 (0.6)ns	14.7 (0.6)
	posture	16.4 (1.3)ns	16.2 (1.5)
	movements	5.9 (0.2)ns	5.9 (0.4)
	tone	22.2 (1.2)ns	22.0 (1.6)
	reflexes	12.4 (1.6)ns	12.3 (1.9)
12 months	**global score**	**73.1 (1.7)ns**	**72.9 (2.4)**
	cranial nerves	14.7 (0.5)ns	14.7 (0.5)
	posture	16.9 (1.0)ns	17.0 (1.1)
	movements	6.0 (0.2)ns	5.9 (0.4)
	tone	22.6 (1.3)ns	22.4 (1.5)
	reflexes	13.0 (1.3)ns	12.9 (1.6)

ns = no statistical differences between the two groups for global and sub-section scores

Statistical analysis

Values of HINE scoring are reported as median, mean, standard deviation (SD) and range at different ages. The frequency distribution of global scores and sub-scores was calculated for each time period (6, 9, 12 months) and a cut-off score corresponding to the 10th percentile was identified. In order to explore the possible influence of GA on HINE scores, differences in sub-scores and global scores between the two sub-groups of infants born at 35 and 36 weeks of GA, were analysed by the Mann-Whitney test.

Results

In the study period 602 consecutive newborns with a GA between 35 and 36. 9 weeks were discharged from our Neonatal Unit; from this population 154 babies were excluded because of major lesions at US scanning (n = 74) or an incomplete follow-up programme (n = 80); 448 infants fulfilled the inclusion criteria; 206 were born at 35 weeks and 242 at 36 weeks GA. Normal cranial US scans were found in 400 infants, whereas transient flares or IVH 1 were observed in 38 and 10 infants, respectively. 50% of the cohort was male. No significant differences between infants born at 35 and those born at 36 weeks were found both for sub-scores and global scores at any time period (**Table 1**). The infants with minor lesions on US had scores that were always within the range observed in the group with normal US. As the magnitude of the scores was not significantly associated with the gestational age at birth or ultrasound findings , the analyses for each time period were performed in the entire population and are shown in **Table 2** that also shows details of the range, median scores and 10th centile cut-off.

Table 2 Median, range and 10th percentile of global and subsection scores

	6 months		9 months		12 months		12 months*	
	Median (Range)	10th p.	Median (Range)	10th p.	Median (Range)	10th p.	Median (Range)	10th p.
cranial nerve	15 (12–15)	14	15 (12–15)	14	15 (13–15)	14	15 (12–15)	15
posture	16 (7–18)	14	17 (8–18)	14	17 (8–18)	16	18 (6–18)	≥16
movements	6 (3–6)	5	6 (3–6)	6	6 (3–6)	6	6 (3–6)	6
tone	21 (16–24)	19	22 (15–24)	20	23 (17–24)	20	24 (17–24)	≥22
reflexes	11 (5–15)	8	13 (7–15)	10	13 (8–15)	11	15 (11–15)	≥13
global score	68 (60–74)	64	72 (63–78)	68	73 (63–78)	70	76 (63–78)	73

*The scores from Haataja et al. [5] are reported in the last column

Table 3 Incidence of findings in the items of subsections posture, tone and reflexes at different ages

	6 months Scores (%)				9 months Scores (%)			
	3	2	1	0	3	2	1	0
posture								
head	79	17	4	0	85	13	2	0
trunk	31	49	20	0	52	39	9	0
arms	85	13	2	0	88	11	1	0
hands	85	12	3	0	90	8	2	0
legs	28	53	18	1	51	40	9	0
feet	92	7	1	0	93	7	0	0
tone								
scarf sign	95	5	0	0	94	6	0	0
passive shoulder elev	50	43	7	0	56	39	5	0
pron/supination	87	12	1	0	91	9	0	0
adductors	79	21	0	0	87	13	0	0
popliteal angle	37	58	5	0	60	38	2	0
ankle dorsiflexion	33	54	13	0	53	43	4	0
pulled to sit	48	40	12	0	73	24	3	0
ventral suspension	78	21	1	0	88	12	0	0
reflexes								
tendon reflexes	73	23	3	0	80	14	6	0
arm protection	43	41	16	0	64	25	11	0
vertical suspension	65	24	10	1	77	18	5	0
lateral tilting	22	43	33	2	32	55	13	0
forward parachute	19	33	48	/	56	27	16	/

Cranial nerves

The 10th percentile cut-off score was 14 (maximum score possible: 15) on all three assessments (6, 9, 12 months), with minimal changes of distribution of scores over time (▶ **Table 2**) for both single item and the global score of this subsection.

Posture

At 6 and 9 months, the 10th percentile cut-off score was 14 (maximum score possible: 18) with a progressive increase of both cut-off and median scores over time (▶ **Tables 2–4**). Trunk and leg posture showed the most marked differences over time.

Movements

At 6 months the 10th percentile cut-off score was 5 (maximum score possible: 6) with minimal changes of both cut-off and median scores at 9 and 12 months (▶ **Table 2**) for both single item and the global score of this subsection.

Tone

At 6 months, the 10th percentile cut-off score was 19, (maximum score possible: 24) while at 9 and 12 months the cut-off score was 20 with a progressive increase of both mean and median scores over time (▶ **Table 2**). ▶ **Tables 3** and **4** show details of findings during the first year of life; passive shoulder elevation, popliteal angle and ankle dorsiflexion were the items that showed the most marked differences over time.

Reflexes

At 6 months the 10th percentile cut-off score was 8 (maximum score possible: 15) with a progressive increase of both cut-off scores and median score that was less marked between 9 and 12 months (▶ **Table 2**). ▶ **Tables 3** and **4** show details of findings during the first year of life.

Global score

At 6 months the global 10th percentile cut-off score was 64 (maximum score possible:78) and there was a progressive increase of both median and mean global score over time. The frequency distribution of global scores (▶ **Fig. 1**) showed a progressive modification of its shape, with more variable distribution of scores at 6 months.

Table 4 Incidence of findings in the items of subsections posture, tone and reflexes at 12 months: comparison with term infants

	12 months (GA 35 to 36.9 weeks) Scores (%)				12 months (GA≥37 weeks)* Scores (%)			
	3	2	1	0	3	2	1	0
posture								
head	94	5	1	0	100	0	0	0
trunk	60	36	4	0	100	0	0	0
arms	93	7	0	0	98	0	2	0
hands	93	7	0	0	100	0	0	0
legs	59	36	5	0	64	25	10	1
feet	94	4	2	0	90	0	10	0
tone								
scarf sign	95	5	0	0	98	0	2	0
passive shoulder elev	56	41	3	0	84	0	16	0
pron/supination	90	10	0	0	100	0	0	0
adductors	89	11	0	0	75	25	0	0
popliteal angle	68	31	1	0	75	25	0	0
ankle dorsiflexion	65	33	2	0	84	13	3	0
pulled to sit	82	16	2	0	100	0	0	0
ventral suspension	90	10	0	0	99	0	1	0
reflexes								
tendon reflexes	83	16	1	0	82	18	0	0
arm protection	68	29	3	0	99	0	1	0
vertical suspension	78	21	1	0	100	0	0	0
lateral tilting	45	47	8	0	75	16	9	0
forward parachute	64	31	5	/	100	0	0	/

*From Haataja et al. [5]

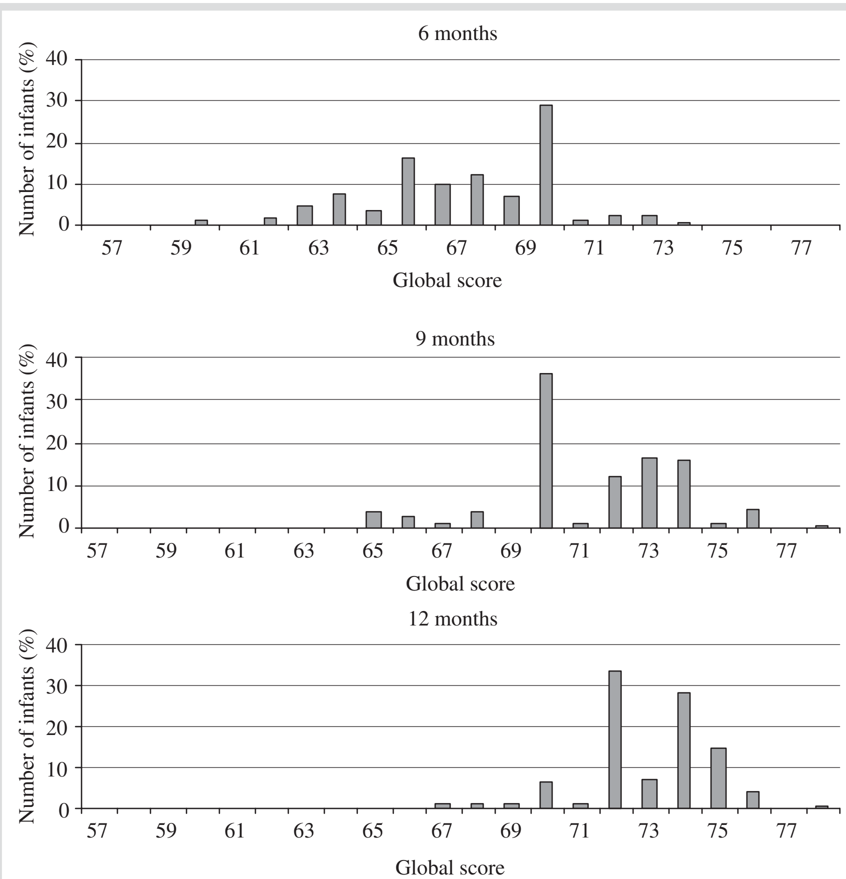

Fig. 1 Frequency distribution of global HINE score at 6, 9 and 12 months.

Discussion

The main aim of this study was to define the frequency distribution of HINE scores in a low-risk near-term population, followed longitudinally at 6, 9 and 12 months corrected age. As we were interested in establishing the spectrum of neurological findings in relatively low-risk near-term infants, we have selected our population on the basis of a normal or nearly normal neonatal US, a neurodevelopmental quotient above or equal to 80 and the absence of cerebral palsy or motor disability. When we analysed the HINE scores in our infants according to their gestational age at birth, we found no significant differences between infants born at 35 and 36 weeks. This lack of difference may be because all infants were born within a two-week interval with over 60% clustering between 35.3 and 36.4 weeks GA, and also because of the strict inclusion criteria. As a consequence of this, in the present study, all the infants were considered as belonging to a single group.

Surprisingly, although our cohort was born only a few weeks before term age, when we applied the optimality score developed for term infants at 12 months [8] to our cohort, only 55% of our infants showed optimal scores when assessed at 12 months CA. The 10^{th} percentile and the median global HINE score of our near-term cohort were lower than in the term population and the differences mainly reflected lower scores in the sub-sections of tone and reflexes. In contrast the scores for cranial nerves, movements and posture were similar to those of term children. These findings were somehow more similar to the HINE scores reported in preterm infants with gestational age <31 weeks, who also had similar differences in tone, posture and reflexes compared to term infants [5–7, 12, 13].

Our findings also provide longitudinal data on the range of neurological scores between 6 to 12 months. So far the data on HINE scores in preterm infants have been limited to assess the prognostic value of the HINE in 74 preterm infants assessed between 9 and 18 months [5]. No systematic study has provided longitudinal information on the spectrum of the various aspects in a cohort of near-term infants.

The results of our study show a progressive increase in global scores with different rates of increase in the different sub-sections. While the 10^{th} percentile for cranial nerve and movement sub-scores was similar throughout the three evaluations, with an increase of only one point between 6 and 12 months of CA, other subsections showed more marked differences over time. It is of note that in our cohort most items assessing tone and posture showed a progressive improvement even after 6 months. These findings are to some extent discordant with those reported in term infants who showed a progressive improvement up to the age of 6 months [10], but little changes at 7, 9 and 12 months. These results therefore indicate that near-term infants continue their neuromotor development with a gradual change toward more normal response by 12 months.

The items that were more often different at 9 and 12 months from those of full-term infants at 9 and 12 months, were arm protection, lateral tilting, forward parachute, trunk and legs posture, passive shoulder elevation, or popliteal angle and ankle dorsiflexion. We were surprised that parachute reaction was incomplete or absent in a proportion of infants at 12 months but similar findings have also been previously reported in another study in full-term infants assessed at 12 months [16]. It is of interest that the incomplete response to lateral tilting, arm protection and forward parachute have also been reported in low-risk preterm infants (<32 weeks) with normal motor outcome examined at 1 year [5] suggesting that in near-term infants these items are more in keeping with those obtained in very preterm than in full-term infants.

In conclusion, our results suggest that the HINE developmental curve in near-term infants shows a lateral shift compared to term infants, with similar scores reached after a short delay. As the follow-up of the present study did not include the use of the HINE at 18 months we cannot exclude that a further increase of HINE scores in near-term infants may be possibly observed even after 12 months of corrected age, allowing them to reach the scoring levels of low-risk term infants. This would be consistent with recently published data on preterm infants (≤32 weeks) investigated with the Alberta scale, who fully reach term infant scores only after 17 months of CA [17].

Our results also suggest that, when examining infants born at 35 and 36 weeks, the criteria of optimality developed in infants born full-term should not be applied, even if they are assessed considering their corrected age.

Because of the robustness of the analysis of our data, based on the number of subjects enrolled, on their high compliance with serial assessments, and on the strict inclusion criteria as to patient selection and outcome definition, the data presented in this paper may provide a reference when examining these infants.

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