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Predictive values of cranial ultrasound and assessment of general movements for neurological development of preterm infants in the Maribor region of Slovenia

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Prädiktiver Wert von Schädelultraschall und Analyse der „General Movements" für die Vorhersage der neurologischen Entwicklung von Frühgeborenen der Region Marburg (Slowenien)

Zusammenfassung. *Ziel der Studie:* Ziel dieser Studie war es, den prädiktiven Wert einerseits des Schädel-Ultraschalls (US) und andererseits der Analyse der „General Movements" (GM) für die Vorhersage der späteren neurologischen Entwicklung von Frühgeborenen der Region Marburg (Slowenien) zu erfassen.

Methoden: Die longitudinal vom Tag der Geburt bis zum chronologischen Alter von 3 Monaten erhobenen Ergebnisse des Schädel-US und die Ergebnisse der GM-Analyse im (bezüglich des errechneten Geburtstermins korrigierten) Alter von 3 Monaten wurden mit den Ergebnissen der traditionellen neurologischen Untersuchung und der Erhebung der psychomotorischen Entwicklung verglichen, die bei denselben Kindern im (korrigierten) Alter von 6 Jahren durchgeführt wurde.

Ergebnisse: 112 Frühgeborene (37. Woche und darunter) wurden in die Studie eingeschlossen:

Je nach Ergebnis der Schädel-US Untersuchung wurden die Kinder als „Hoch-" oder „Niedrigrisiko" in Bezug auf neurologische Schäden eingestuft. Von den 83 Kindern, die durch Schädel-US als „Niedrigrisiko" eingestuft wurden, hatten 74 (89%) tatsächlich eine völlig normale neurologische Entwicklung. Von den „Hochrisiko-" Kindern hatten 21 (72%) von 29 Kindern eine gestörte neurologische Entwicklung.

Von 77 Kindern mit normalen GM hatten 73 (95%) ein normales neurologisches Ergebnis und 4 (5%) eine neurologische Störung. Von 35 Kindern mit abnormalen oder fehlenden GM hatten 26 (74%) eine abnormale und 9 (26%) eine normale neurologische Entwicklung.

Von den insgesamt 30 Kindern mit pathologischer neurologischer Entwicklung zeigten 16 zerebrale Lähmungserscheinungen (ZL), ein Kind mentale Retardierung (MR), neun Kinder sowohl ZL als auch MR und 4 Kinder geringgradige komplexe neurologische Störungen.

Die Schädel-US Untersuchung hatte also eine Richtigkeit von 85% mit einer Sensitivität von 70% und einer Spezifität von 90%; der positive Voraussagewert lag bei 72% der negative bei 89%. Die GM-Analyse hatte eine Richtigkeit von 88% mit einer Sensitivität von 87% und einer Spezifität von 89%, einen positiven Vorhersagewert von 74% bzw. einen negativen von 95%.

Schlussfolgerung: Die Sensitivität des Schädel-US war eindeutig niedriger als die der Analyse der GM. Die Spezifität beider Methoden ist in Bezug auf ihren Vorhersagewert bezüglich bleibender neurologischer Schäden von Frühgeborenen fast gleich.

Summary. *Objective:* The aim of the study was to assess the predictive values of cranial ultrasound (US) scans and assessment of general movements of fidgety character (GMs) for the later neurological development of preterm infants in the Maribor region of Slovenia.

Methods: Results of cranial US scans done longitudinally from the day of birth until the end of three months of chronologic age and results of GMs at three months of corrected age were compared with traditional neurological examination and evaluation of psychomotor development of the same children at the corrected age of six years.

Results: A total of 112 preterm infants (gestational age 37 weeks and below) were included in the study. The infants were classified as low-risk or high-risk for neurological impairment on the basis of cranial US scans. The scans classified as low-risk were followed by a normal neurological outcome in 74 (89%) of 83 infants; those classified as high-risk for neurological impairment were followed by abnormal neurological outcome in 21 (72%) of 29 infants. Of 77 infants with normal fidgety movements, 73 (95%) had a normal neurological outcome and 4 (5%) had an abnormal neurological outcome; of 35 infants with abnormal or absent fidgety movements, 26 (74%) had an abnormal neurological outcome and 9 (26%) had a normal neurological outcome. Of 30 children with abnormal outcome, cerebral palsy was diagnosed in

16, mental retardation in one, nine children had both of these, and four had complex minor neurological dysfunction. The validity of the scans was 85%, sensitivity 70%, specificity 90%, positive predictive value 72% and negative predictive value 89%; the validity of the GMs was 88%, sensitivity 87%, specificity 89%, positive predictive value 74% and negative predictive value 95%.

Conclusions: The sensitivity of the cranial US scans was clearly lower than that of assessment of general movements of a fidgety character.

The specificities of the two methods were almost the same.

Key words: Infant, premature, ultrasound, neurological examination, predictive value.

Introduction

In parallel with the development of health care and intensive care for children born at gestational age below 37 weeks, technical methods that facilitate prediction of neurological prognosis in these children have been developed. Cranial ultrasound (US) is one such method [1] and ensures more complete information on the state of the central nervous system, especially in children in whom intensive care and treatment procedures often make classic neurological examination difficult. US has the advantage of being a bedside procedure; it is noninvasive and can be repeated whenever needed without producing damage to the patient. Magnetic resonance imaging (MRI) also allows precise structural localization of the lesions. Other means of assessing a brain injury related to outcome include positron emission tomography (PET), single photon emission computed tomography (SPECT), evoked response techniques and continuous cerebral function monitoring, and their potential value is probably great. Which of these methods is actually in use seems to be primarily based on the local interest and local facilities.

There are many neurological methods that may be used in examination of newborns, infants and small children. A developmental neurologist uses them to assess whether or not the neurological development of a child is and probably would be normal. It is very important that the technique of the neurological examination is as simple, noninvasive and as easily repeatable as possible. Assessment of general movements of fidgety character (GMs) is such a method [2–4].

The aim of our study was to determine the validity, sensitivity, specificity, and positive and negative predictive values of cranial US scans and GMs in a large group of preterm infants in the Maribor region of Slovenia, and to compare our results with the results, opinions and conclusions of other studies.

The hypothesis was that the validity, sensitivity, specificity, and positive and negative predictive value of cranial US scans would be lower than that of GMs, because the information on the central nervous system obtained by US differs from the information obtained by neurological examination. The US provides information on the structure of the central nervous system, whereas neurological examination gives information on the function of that structure.

Participants and methods

Participants

The present study is a follow-up of a study in 1994–2000, which was published in the Croatian Medical Journal in 2003 [5]. In the earlier study, the predictive value of GMs was compared with that of neurological examination according to Amiel-Tison and Grenier in a large group of neurologically high-risk preterm infants (gestation age 37 weeks and below). For this purpose two groups were formed: experimental and control groups. Infants with three or more antenatal, perinatal and neonatal risk factors were classified as at high risk of developing neurological deficits, i.e. neurologically high-risk preterm infants. The risk factors were described in detail [5]. The children from the experimental group also had serial cranial US scans done.

For the present follow-up study, 112 children from the former experimental group of 120 preterm infants were re-examined at the corrected age of six years, which is the age when the diagnosis of cerebral palsy (CP) is considered reasonably stable [6]. Between December 1, 2000, and June 30, 2005, the children were again examined at the Center for Children with Developmental Disabilities (CCDD), Dispensary for Children, Maribor Public Health Center (MPHC), Maribor, Slovenia, at their corrected age of six years. Eight of the 120 infants in the earlier study were lost to follow-up because they discontinued coming to examinations. In the first study, infants were selected using random number tables among 930 preterm infants referred to the CCDD for neurological examination and follow-up. During the randomization the following groups of infants were excluded: (i) those who did not have three or more risk factors (n = 350); (ii) those whose parents refused to participate (n = 16); (iii) those with birth anomalies of the central nervous system and/or other organs or organ systems, those with clinical signs of known syndromes that could be recognized in the newborn and infants [7], and those at risk of inheriting neurological disorders (n = 9); and (iv) those who were not examined by an experienced neonatologist performing all the US scans (n = 323). The infants were born at the Department of Gynecology and Obstetrics, General Hospital Maribor between January 13, 1994 and December 30, 1998. The delivery date for the children was calculated on the basis of the date of the mother's last menstrual period. The hospital pediatrician-neonatologists assessed the gestational age of the infants according to Farr et al. [8], precisely defining the earliest gestation age at 28.1 weeks; gestational age below that was assessed according to US and the date of the mother's last menstrual period. In Maribor, by agreement, all preterm infants were referred to the CCDD at the age of three months by the pediatrician-neonatologists, general pediatricians or general practitioners. A detailed medical history was obtained for all infants. All medical records from the hospital maternity wards were reviewed and neurological development risk factors noted. The medical history was completed as needed during the follow-up visits. Each child has undergone all the examinations planned for the study.

The Commission for Medical Ethics of the Slovenian Ministry of Health established appropriateness of the study from the ethical point of view and allowed it to be carried out in accordance with the Slovenian Code of Medical Deontology and principles of the Helsinki Declaration on Biomedical Research on Humans (Hong Kong, 1989). Written informed consents were obtained from parents whose children were included in the study.

Methods

Cranial ultrasound scans

An Ultramark 4 (ATL, Bothell, Washington, USA) with moving two-dimensional images and a multifrequency sector transducer (5–7,5 MHz) was used for all cranial US examinations, which were made by an experienced neonatologist in the intensive care unit at the Division of Neonatology, University Department of Gynecology and Obstetrics, and University Department of Pediatrics, Maribor General Hospital. A special protocol was developed by the neonatologist and was included in the medical files of each patient. The transducer was placed on the anterior fontanel, which provided an acoustic window. Five standard sections in the coronal plane and three standard sections in the sagittal plane were made. The structure of the brain tissue was assessed in all the sections. Dimensions of the ventricular system were determined and evaluated, and morphological changes described. The width of the subarachnoid space in the area of the longitudinal fissure and the sylvian fissure was determined on the first coronal section [9].

The first US examination of the brain took place within the first week after birth in all the infants; optimal timing of this examination was within the first four days after birth. The timing of the follow-up US examinations of the brain depended on the type of pathology found at the first examination and on the appearance of neurological problems in these children: if the first US findings and the neurological status of a child at that age were pathological, follow-up examinations were performed at the age of 7 days, 14 days, three weeks, one month, two months and three months; if the findings of the first US examination of the brain and the neurological status of a child at that age were normal, the examination at 7 days was omitted from the series of follow-ups. The US finding was assessed as normal if echogenicity of the brain tissue was adequate, the dimensions and form of the ventricular system were normal, and if no dilatation of the external subarachnoid space was present [10].

Periventricular hemorrhage (PVH) and intraventricular hemorrhage (IVH) were graded I–IV according to Papile's classification [11]. Hypoxic-ischemic lesions were classified as grade I–IV periventricular leucomalacia (PVL), according to de Vries [1].

Assessment of the US findings of the brain was simplified to make the presentation clearer and statistical analysis of the data easier. To make an assessment as objective as possible, several US examinations are needed within a month after birth because pathohistological changes in the brain may persist, progress or decrease. On the basis of all the US examinations in the first month of life and at the follow-up at the age of three months, the children were divided into two groups, as follows:

1) a group at low risk for neurological impairment on the basis of the US findings, which included all those with normal US findings or grade I PVH-IVH (subependimal hemorrhage) and/or transient periventricular echodensities persisting longer than seven days (grade I PVL);
2) a group at high risk for neurological impairment on the basis of the US findings, which included all those with grades II–IV PVH–IVH according to Papile and/or grades II–IV PVL according to de Vries.

Assessment of general movements of fidgety character

A young infant has a repertoire of distinct and spontaneous movement patterns. One set of these is known as general movements (GM). These are complex, frequent and long lasting, and changes in their normal quality are a reliable indicator of brain dysfunction [12]. GM were assessed in all the children at the corrected age of 12 weeks (the corrected age is the age calculated from the day of the calculated delivery date, whereas the chronologic age is the age of a child since the day of birth), according to the recommendations in the literature [12]. All the GM assessments were made by the author, who also designed the protocol. At the time of the assessments, the author was blind to the results of the US scans; these were stored and available only to the neonatologist who performed them. The recordings of the children's GM were made on videotape and reviewed on video-recorder. The GM were recorded in the active wakefulness state 4, according to Prechtl. Global assessment of GM quality (normal, abnormal or absent) was based on the observer's visual Gestalt perception [5]. Normal fidgety movements were defined as restless smoothly rounded movements involving the whole body. They were circular movements of small amplitude, moderate speed and variable acceleration of the neck, trunk and limbs in all directions. They were continual in an awake infant, except during focused attention, fussing or crying. Fidgety movements were assessed as abnormal if they looked like normal fidgety movements but their amplitude, speed and jerkiness were moderately or greatly exaggerated, or absent if they were never observed [4, 12]. The expected neurological development of the child was determined as normal if the GM were normal, and as abnormal if the GM were abnormal or absent. The results of the GMs were written in a paper protocol which was then sealed and stored within the CCDD in the care of a local administrator.

Neurological examination, diagnosis of cerebral palsy, and assessment of psychomotor development

The modified Touwen test [13] was used by the author for assessment of the children's motor development at six years of corrected age. At the time of the examination the author was

Table 1. Relation of cranial ultrasound scans at three months of age and neurodevelopmental outcome at the corrected age of six years

	Cranial US scans at three months of age (n = 112)	Neurodevelopmental outcome at the corrected age of six years (n = 112)				
	Number of children	Normal and MND-S	Cerebral palsy only	Mental retardation only	Cerebral palsy and mental retardation	MND-C
Low-risk	83	74 (89.2%)	6 (7.2%)	1 (1.2%)	2 (2.4%)	0 (0.0%)
High-risk	29	8 (27.6%)	10 (34.5%)	0 (0.0%)	7 (24.1%)	4 (13.8%)

n number of children; *US* ultrasound; *MND-S* simple minor neurological dysfunction; *MND-C* complex minor neurological dysfunction.

blind to the results of both the US scans and the assessment of GMs. A modified partial Touwen test was used to detect minor neurological dysfunction (MND) and major neurological impairment. MND was defined as developmental coordination disorder with normal intelligence and without evidence of major neurological impairment or cognitive impairment [14]. According to Hadders-Algra, findings of the neurological examination can be grouped into six functional categories [15]. Results of the neurological examination were therefore classified either as normal outcome; as simple MND (MND-S) if there were one or two of the six abnormal functional categories; as complex MND (MND-C) if there were three or more abnormal functional categories; or as CP. The diagnosis of CP was made exclusively on the basis of the clinical picture [6, 16] and, according to the clinically most pronounced neurological signs, was divided into spastic, ataxic, dyskinetic and hypotonic types. The spastic type included spastic hemiparesis, spastic diplegia and spastic quadriplegia [17]. The children with CP were divided into five groups with respect to gross motor function according to Palisano et al. [18]: minimal, mild, moderate, moderately severe and severe CP. For the final assessment of neurological development, results of psychomotor examination at the corrected age of six years were also taken into account. Psychomotor development was evaluated by clinical psychologists at the Clinic for Pedopsychiatry, MPHC, Maribor, using the Brunet-Lezin test and Vineland scale of social maturity of the child, standardized for the Slovenian population of children [19]. From the global development quotient (DQ), a partial quotient of motor abilities was excluded if it was below 80 in all children with neuromotor development deviating from normal. If the DQ was under 80 (with excluded partial quotient of motor abilities under 80), the child was assessed as mentally retarded. If the DQ was 54–80 the child was assessed as slightly mentally retarded, if the DQ was 39–53 the child was assessed as moderately mentally retarded, if the DQ was under 39 the child was assessed as heavily mentally retarded. Neurological development of a child with normal movement patterns, MND-S and normal mental development was evaluated as normal. The neurological development was evaluated as abnormal if a child had MND-C, CP of any kind [16, 17] or degree [18] and/or delayed mental development, including mental development slightly below normal (DQ 54–80). Assessment of neurological development at the corrected age of six years was used as the gold standard for comparison with results of the cranial US scans and assessment of GMs.

Statistical analysis

Statistical methods remained the same as in the previous study [5]. Data were analyzed using standard statistical methods and Microsoft Office Excel 2003 (Windows XP, Microsoft Corporation, Redmond, WA, USA). Qualitatively changeable variables, such as the US scans, GMs, neurological examination, assessment of psychomotor development, and CP diagnosis were expressed as frequency, in absolute numbers and as percentages. Validity, sensitivity, specificity, and positive and negative predictive values of cranial US scans and assessment of GM were calculated in accordance with recommendations from the literature [20] and compared with the results of neurological examination at the corrected age of six years.

Results

The final study sample included 112 infants: 57 boys and 55 girls with gestational ages 26–37 weeks (median: 33). Their birth weights ranged from 660 g to 3820 g (median: 1975). Of the 112, 74 (66%) infants had more than five risk factors for neurological development (median: 6; minimum 3, maximum 13). The number of infants from single pregnancy was 58, from twin pregnancy 51 and from triplet pregnancy 3. CP was diagnosed in sixteen children, MR in one, nine had both CP and MR, whereas four had MND-C. Twelve had MND-S, 70 had completely normal neurodevelopmental outcome. Twenty-one infants (19%) were small for gestational age: CP was diagnosed in three, CP and MR in two, the others had completely normal neurodevelopmental outcome.

Cranial ultrasound scans

The relation of results of the cranial US scans to the neurological outcome at the corrected age of six years is shown in Table 1.

Quality of general movements of fidgety character

The results of GM assessment and the neurological outcome at the corrected age of six years are shown in Table 2.

The cranial US scans gave nine false-negative results and the GMs four. One child had false-negative results by both methods but had mental retardation (Table 3). The cranial US scans gave eight false-positive results and the GMs nine. Five of the children had false-positive results by both methods and had normal neurological outcome (Table 4).

Validity of the scans was 85%, sensitivity 70%, specificity 90%, positive predictive value 72% and negative predictive value 89%. Validity of GM assessment was 88%, sensitivity 87%, specificity 89%, positive predictive value 74% and negative predictive value 95% (Table 5).

Table 2. Relation of assessment of general movements of fidgety character at three months of corrected age and neurodevelopmental outcome at the corrected age of six years

	GMs at corrected age of three months (n = 112)	Neurodevelopmental outcome at corrected age of six years (n = 112)				
	Number of children	Normal and MND-S	Cerebral palsy only	Mental retardation only	Cerebral palsy and mental retardation	MND-C
Normal	77	73 (94.8%)	1 (1.3%)	1 (1.3%)	0 (0.0%)	2 (2.6%)
Abnormal	16	9 (56.2%)	5 (31.3%)	0 (0.0%)	0 (0.0%)	2 (12.5%)
Absent	19	0 (0.0%)	10 (52.6%)	0 (0.0%)	9 (47.4%)	0 (0.0%)

n number of children; *GMs* the assessment of general movements of fidgety character; *MND-S* simple minor neurological dysfunction; *MND-C* complex minor neurological dysfunction.

Discussion

Use of cranial US as a noninvasive method in neonatal units and intensive care units for newborns and infants is widespread and extremely necessary. Since its beginning, the cranial US has been considered the best predictor of future neurological outcome [1]. However, further studies on the relationship between US findings and neurological outcome in neurologically low-risk preterm and neurologically low-risk and high-risk term infants have revealed that GM assessment is superior to US findings [3, 4]. Maas and colleagues [21], who evaluated a large number of low-risk preterm infants around term age, established that both cranial US and GM assessment had high specificity but that GMs had higher sensitivity. Our study included a large group of neurologically high-risk preterm infants and showed that cranial US had lower sensitivity but almost the same specificity as GMs. Normal GMs were better predictors of normal neurological development than the low-risk finding on cranial US, but there was almost no difference between abnormal or absent GMs and the high-risk finding on cranial US in predicting abnormal neurological development. The hypothesis that the validity, sensitivity, specificity, and positive and negative predictive value of the cranial US scans would be lower was confirmed for sensitivity and negative predictive value, but was not confirmed for validity, specificity and positive predictive value.

Bos et al. [22] found that a large proportion of preterm infants with abnormal GMs have normal findings on brain US scans. This suggests that chronically reduced fetal supply of oxygen and nutrients may lead to longer-lasting but often transient brain dysfunction, which is not necessarily caused by hemorrhagic or hypoxic-ischemic lesions detectable on US scans. We came to the same conclusions in our study. Among nine infants who had abnormal GMs but completely normal neurological outcome or MND-S, six had US scans classified as low-risk for neurological impairment. The longer-lasting but often transient brain dysfunction not easily detectable on US scans could also be the cause of the relatively high number of false-positive results for GMs and, at the same time, of the relatively high number of false-negative cranial scans in our study. We think that this explains in part the low sensitivity of cranial US scans; the use of more advanced machines and transducers will probably improve the sensitivity of US.

On the basis of another study, Bos et al. [23] concluded that, in infants with transient echodensities, longitudinal assessment of GMs helps to determine if there is brain dysfunction, either transient or persistent, and identifies infants at risk of abnormal neurological development. Pisani et al. [24] demonstrated that infants with transient echodensities show neurodevelopmental outcome that is identical to that of infants with steadily normal brain ultrasound findings, and conclude that little is known about the clinical evolution and neurological sequelae of transient periventricular echodensities in the neonatal period. Others think that the duration, but not the grading, of transient periventricular echodensities is significantly correlated with neurodevelopmental outcome [25, 26]. Many authors think that the majority of brain injuries in preterm infants occur in white matter [27–29]. Most of the lesions are diffuse rather than focal or cystic. All of the authors agree that cranial US is an excellent method for detecting severe damage to the white matter, and that severe cranial US abnormalities strongly predict motor disability. They also agree that, for less severe lesions without extensive cystic and punctate hemorrhages in the white matter, the combination of US with other methods such as MRI and GMs helps to determine if there is brain dysfunction [23, 27, 29]. This could also be the explanation for the relatively high number of false-positive US scans in our study:

Table 3. Children with false-negative cranial ultrasound scans (participants 1–9, shaded area on the left side of the table); children with false-negative results on assessment of general movements of fidgety character (participants 9–12, shaded area on the right side of the table); and child with false-negative results in both methods (participant 9)

Participant	False-negative cranial US scans (shaded area only)	Neurological outcome at six years of corrected age	False-negative GMs (shaded area only)
1	PVH-IVH I	A moderate form of spastic diplegia	Absent
2	PVH-IVH I	A moderate form of spastic diplegia and mental retardation slightly below normal	Absent
3	PVH-IVH I	A mild form of spastic diplegia	Abnormal
4	PVH-IVH I + PVL I	A moderate form of cerebral palsy of hypotonic type and a moderate mental retardation	Absent
5	PVH-IVH I + PVL I	A mild form of spastic hemiparesis	Abnormal
6	PVH-IVH I + PVL I	A mild form of spastic diplegia	Abnormal
7	PVL I	A minimal form of spastic diplegia	Abnormal
8	PVL I	A minimal form of spastic diplegia	Abnormal
9	Normal	Mental retardation slightly below normal	Normal
10	PVH-IVH III + PVL II	Minor neurological dysfunction-complex	Normal
11	PVH-IVH III + PVL III	A moderately severe form of spastic diplegia	Normal
12	PVH-IVH III	Minor neurological dysfunction-complex	Normal

GMs the assessment of general movements of fidgety character; *IVH* intraventricular hemorrhage; *PVH* periventricular hemorrhage; *PVL* periventricular leucomalacia; *US* ultrasound.

Table 4. Children with false-positive cranial ultrasound scans (participants 1–8, shaded area on the left side of the table); children with false-positive results on assessment of general movements of fidgety character (participants 6–14, shaded area on the right side of the table) and children with false-positive results in both methods (participants 6–8)

Participant	False-positive cranial US scans (shaded area only)	Neurological outcome at six years of corrected age	False-positive GMs (shaded area only)
1	PVH-IVH II	Normal	Normal
2	PVL II	Normal	Normal
3	PVL II	Normal	Normal
4	PVL II	Normal	Normal
5	PVH-IVH I+PVL II	Normal	Normal
6	PVL II	Normal	Abnormal
7	PVL II	Normal	Abnormal
8	PVL II	Normal	Abnormal
9	PVH-IVH I	Normal	Abnormal
10	PVH-IVH I	Normal	Abnormal
11	PVH-IVH I	Normal	Abnormal
12	PVL I	Normal	Abnormal
13	PVL I	Normal	Abnormal
14	Normal	Normal	Abnormal

GMs assessment of general movements of fidgety character; *IVH* intraventricular hemorrhage; *PVH* periventricular hemorrhage; *PVL* periventricular leucomalacia; *US* ultrasound.

grade II PVL in six infants, grade II PVH-IVH in one infant and grade I PVH-IVH with grade II PVL in another, all of whom had completely normal neurological outcome. By definition, grade II PVL [1] includes periventricular echodensities evolving into small localized frontoparietal cystic lesions and grades I and II PVH-IVH [11] are not at all extensive.

The risk of developing CP and the severity of motor problems increase with the grades of PVH-IVH and PVL [30]. Our study also showed these findings: all the children with a combination of grade III or IV PVH-IVH with grade III or IV PVL had CP and poorer cognitive development.

The great limitation of our study was that the reliability of GM assessment with regard to interscorer variability could not be determined. In order to make the study more objective, the video tapes of GM of the children in the follow-up study should be re-evaluated after a certain period of time. This was done in the previous study, where the intrascorer agreement, calculated as a ratio between the same scores versus all scores, was 97% [5]. However, it was not possible to do this with the majority of the children because the video tapes were made between 1994 and 1998, when the technology of making and storing video tapes was still rather complicated and expensive. For this reason, many video tapes were re-taped and therefore lost. Only the written results remain, prepared in accordance with a specially designed protocol. Modern DVD cameras and the possibility of storing videos on PCs will allow better objectivity in the future, as the material will then be better accessible to a larger number of independent scorers.

Table 5. Validity, sensitivity, specificity, and positive and negative predictive values of cranial US scans and assessment of general movements of fidgety character

	Cranial US scans	GMs
Validity	85%	88%
Sensitivity	70%	87%
Specificity	90%	89%
Positive predictive value	72%	74%
Negative predictive value	89%	95%

US ultrasound; *GMs* assessment of general movements of fidgety character.

The combination of GM assessment with US scans has recently attracted the attention of other specialists. Using four-dimensional US to assess fetal behavior in all three trimesters of normal pregnancy, Kurjak et al. concluded that fetal behavior patterns directly reflect the developmental and maturation processes of the central nervous system [31]. They expect that four-dimensional US observation of fetal movements may lead to a better understanding of the neurological development of the fetus. With this method, development neurologists are coming closer to the possibility of obtaining data on abnormal movement patterns of the fetus as early as the time of birth. This will be very important for the children from high-risk pregnancies in particular and may also add important information on the etiology of CP, especially when prenatally acquired.

From the results of our study we conclude that the combination of cranial US and assessment of GM is very successful in detecting neurological impairment in high-risk preterm infants, particularly those with minor ultrasound abnormalities, and is particularly suitable in hospitals where more sophisticated methods such as MRI, evoked response techniques, continuous cerebral function monitoring, PET and SPECT are not yet part of the daily routine.

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