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ABSTRACT. *Objective.* **The Bayley Scales of Infant Development, Second Edition (BSID II) are commonly used to assess outcomes of extremely low birth weight (ELBW) infants. We sought to assess the predictive validity of the BSID II Mental Developmental Index (MDI) for cognitive function at school age.**

Design/Methods. **Of 330 ELBW infants admitted in 1992–1995, 238 (72%) survived to the age of 8 years, of whom 200 (84%) were tested at both 20 months' corrected age (CA) and 8 years. Mean birth weight was 811 g, mean gestational age was 26.4 weeks, 41% were boys, and 60% were black. Measures included the BSID II at 20 months' CA and the Kaufman Assessment Battery for Children (KABC) Mental Processing Composite (MPC) at 8 years' postnatal age. BSID II MDI and MPC scores were compared and the predictive validity calculated for all 200 ELBW children and for the 154 ELBW neurosensory-intact subgroup. Predictors of stability or change in cognitive scores were examined via logistic regression adjusting for gender and sociodemographic status.**

Results. **For all ELBW children, the mean MDI was 75.6 ± 16 versus a mean KABC of 87.8 ± 19. For the neurosensory-intact subgroup, the mean MDI was 79.3 ± 16 and the mean KABC was 92.3 ± 15. Rates of cognitive impairment, defined as an MDI or KABC of <70, dropped from 39% at 20 months' CA to 16% at 8 years for the total ELBW population and from 29% to 7% for the neurosensory-intact subgroup. The positive predictive value of having an MPC of <70 given an MDI of <70 was 0.37 (95% confidence interval [CI]: 0.27, 0.49) for all ELBW infants, 0.20 (95% CI: 0.10, 0.35) for the neurosensory-intact subgroup, and 0.61 (95% CI: 0.42, 0.77) for the neurosensory-impaired subgroup. The negative predictive values were 0.98, 0.99, and 0.85 for the 3 groups, respectively. Neurosensory impairment at 20 months' CA predicted lack of improvement of cognitive function (odds ratio: 6.9; 95% CI: 2.4, 20.2). Children whose cognitive scores improved between 20 months and 8 years had significantly better school performance than those whose scores stayed at <70, but they did less well than those whose scores were persistently >70.**

Conclusions. **The predictive validity of a subnormal MDI for cognitive function at school age is poor but better for ELBW children who have neurosensory impairments. We are concerned that decisions to provide intensive care for ELBW infants in the delivery room might be biased by reported high rates of cognitive impairments based on the use and presumptive validity of the BSID II MDI.** *Pediatrics* **2005;116:333–341;** ***extremely low birth weight, prematurity, outcome, prediction, intelligence, school age.***

ABBREVIATIONS. ELBW, extremely low birth weight; MDI, Mental Developmental Index; BSID II, Bayley Scales of Infant Development, Second Edition; CA, corrected age; MPC, Mental Processing Composite; SES, socioeconomic status; CI, confidence interval; VLBW, very low birth weight.

The increased survival of infants of extremely low birth weight (ELBW) in the 1990s, which resulted from advances in perinatal care, has been accompanied by high rates of neonatal complications and neurodevelopmental sequelae including cerebral palsy and subnormal cognitive function.[1–3] Rates of neurodevelopmental impairment are used as a primary outcome measure for neonatal therapeutic trials[4,5] and as a measure of the overall quality of survival.[1–3,6–8] They have also been used to establish guidelines for delivery room care of infants born

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at the limits of viability and to counsel parents both before the birth of their infants and during the neonatal hospital stay.[9–13]

The Mental Developmental Index (MDI) of the Bayley Scales of Infant Development, Second Edition (BSID II)[14,15] is the most commonly and widely used measure of cognitive function in high-risk and preterm infants. A subnormal MDI score of <70 (ie, less than −2 SDs) at 18 to 20 months' corrected age (CA) is the most prevalent of the components of what is defined as "neurodevelopmental impairment," which also includes major neurosensory abnormalities.[1,2,4,7,16] Thus, subnormal MDI scores play a major role in determining the rates of impairment quoted in the literature.[1–3,6,8,12] It is unclear, however, to what extent the MDI is predictive of later cognitive function among ELBW infants.

The objective of the present study was to assess the predictive validity of the Bayley II MDI at 20 months' CA (postmenstrual plus postnatal age) for 8-year cognitive function in ELBW (<1000 g) children. We specifically sought to examine whether children who had a subnormal MDI at 20 months' CA were categorized similarly on cognitive testing at school age. We also sought to examine the correlates of stability or change in cognitive test scores between 20 months and 8 years of age.

POPULATION AND METHODS

The study population was drawn from a cohort of 344 ELBW infants admitted to the neonatal intensive care unit at Rainbow Infants and Children's Hospital (University Hospitals of Cleveland, Cleveland, OH) during the 4-year period of 1992–1995. Outcome results of this cohort at 20 months' CA were reported previously.[1] Ten children with major congenital malformations and 1 with AIDS were initially excluded from the population before 20 months' CA, and an additional 2 children (1 later diagnosed with AIDS and 1 with tuberous sclerosis) were excluded after the 20-month visit. One additional child who was ventilator dependent died at 3 years of age. Of the 330 children who did not have major congenital malformations or congenital infections, 238 (72%) survived to a mean age of 8 years. Of these survivors, 219 (92%) were examined at this time as part of a comprehensive study of school-age outcomes, of whom 200 were seen at both 20 months and 8 years of age and constitute the study population. They represent 84% of the birth cohort of survivors and 92% of those who had an MDI at 20 months. Of the 38 children who were not seen at both 20 months and 8 years of age, 18 were seen only at 20 months, 19 were seen only at 8 years, and 1 child was not seen at either time period.

A description of maternal demographic factors, infant birth data, and neonatal risk factors is presented in Table 1. The children had a mean birth weight of 811 g and a mean gestational age of 26.4 weeks. At 20 months' CA, 46 (23%) had a neurosensory abnormality that included either a major neurologic abnormality (mainly cerebral palsy) and/or unilateral or bilateral blindness or deafness.

The 200 study children who had both 20-month-CA and 8-year cognitive assessments, when compared with the 18 children who had a 20-month-CA assessment but were not seen at 8 years, did not differ in mean birth weight (811 vs 814 g) or gestational age (26.4 vs 26.3 weeks). They had lower rates of neurosensory impairment (46 [23%] vs 6 [33%]), subnormal MDI < 70 (78 [39%] vs 11 [61%]), and overall neurodevelopmental impairment (91 [46%] vs 11 [61%]), but these differences were not significant.

A comparison group of school-aged children born at term gestation was recruited as part of the 8-year assessment by randomly selecting a term child from the same school who was within 3 months of age and of the same race and gender as the ELBW child.

TABLE 1. Maternal Demographic Risk Factors, Infant Birth Data, and Neonatal Risk Factors

	$N = 200$
Maternal demographic data*	
Age, y, mean ± SD	27.5 ± 6
Married status, *n* (%)	50 (50)
Black race, *n* (%)	121 (60)
Education	
<High school, *n* (%)	26 (13)
High school, *n* (%)	74 (37)
>High school, *n* (%)	100 (50)
Infant birth data	
Birth weight, g, mean ± SD	811 ± 125
Gestational age, wk, mean ± SD	26.4 ± 2
Male gender, *n* (%)	81 (41)
Multiple birth, *n* (%)	35 (18)
Small for gestational age, *n* (%)†	46 (23)
Neonatal risk factors	
Chronic lung disease, *n* (%)‡	88 (44)
Discharge on oxygen, *n* (%)§	61 (31)
Periventricular hemorrhage	
Grade I or II, *n* (%)	73 (37)
Grade III or IV, *n* (%)	26 (13)
Periventricular leukomalacia, *n* (%)	14 (7)
Ventricular dilatation at discharge, *n* (%)	29 (15)
Severely abnormal cerebral ultrasound, *n* (%)‖	48 (24)
Duration of hospital stay, d, mean ± SD	96 ± 39

* At the time of the child's birth
† Birth weight less than −2 SD for gestational age.[61]
‡ O_2 dependence at 36 weeks' CA.[17]
§ Includes children referred to home and to a chronic care facility.
‖ Includes grade III or IV bleed, periventricular leukomalacia, or ventricular dilatation at discharge.

Data Collection

Maternal sociodemographic descriptors and perinatal and neonatal data were collected prospectively from birth as part of our comprehensive neonatal database. Demographic data included maternal age, race, marital status, and level of education. Neonatal data included the presence of chronic lung disease (bronchopulmonary dysplasia), defined as an oxygen dependence at 36 weeks' CA,[17] and the most severe cranial ultrasound abnormality during the hospital stay, defined as grade III or IV hemorrhage,[18] periventricular leukomalacia, or persistent ventricular dilatation at the time of discharge home.

Follow-up Assessments and Care

All ELBW infants were followed serially from birth as part of the high-risk follow-up program. At the time of neonatal discharge, they were referred to early-intervention services. The rates of compliance and the type and intensity of such services were highly variable. Additional referrals for therapy such as occupational, speech, or physical therapy were made if neurodevelopmental delays were identified during the course of follow-up. A physical examination and neurologic assessment was performed at 20 months' CA.[19] Major neurologic abnormalities at 20 months' CA included cerebral palsy (spastic diplegia, hemiplegia, triplegia, or quadriplegia), hypertonia, hypotonia, and shunt-dependent hydrocephalus without other neurologic abnormality. Hypertonia was defined as a neurologic abnormality if there was a moderate increase in muscle tone that was not considered to be severe enough to define as cerebral palsy. Both hypertonia and hypotonia were included in the category of major neurologic abnormality at 20 months' CA, because these conditions are considered by some to represent a variant of cerebral palsy. Shunt-dependent hydrocephalus without neurologic abnormality was included as an impairment according to the World Health Organization.[20] Sensory abnormality included unilateral or bilateral blindness or deafness. Formal hearing tests were not routinely performed at 20 months' CA. The presence of hearing loss at 20 months' CA was based on the need for hearing aids and/or the mother's report of hearing loss with confirmation from the audiologist report.

The revised BSID II were administered at a mean of 20 months' CA.[15] The BSID II include 2 subscales, a mental scale yielding an

MDI and a motor scale resulting in a Psychomotor Developmental Index. Each has a mean score of 100 and SD of 15. Children with scores of <70 are classified as significantly delayed. Only the MDI was considered for the purpose of this present study. The MDI had a good test-retest stability and interscorer agreement.[15] It includes 178 items of increasing difficulty that measure performance in the areas of sensory perception, knowledge, memory, problem solving, and early language. Item sets that include ~25 items are designated for each age level, with considerable overlap of ages. The MDI is based on the raw score obtained on the item set in which both basal and ceiling criteria are met. Testing of the subjects was started at the age range corrected for prematurity according to suggestions of the Psychological Corporation[21] and other reports.[22,23] After initiation of testing at the CA, the examiner dropped down to lower levels if the child did not obtain a basal level by passing at least 5 items in an item set. Similarly, the examiner attempted to obtain a basal level at a higher range if the child failed <3 items at the corrected age level. If a child obtained an MDI of <50, it was recorded as a score of 50.

At a mean postnatal age of 8.6 years, a complete physical and neurologic examination was performed by a pediatrician, and a caregiver (usually the mother) was interviewed to obtain current demographic, health, and developmental data. At this time prior early-intervention services were recorded. Sociodemographic information included maternal education and marital status as well as the median family income and percent of the population living below the poverty level according to the 2000 census tract of the family's residence. Hearing was measured with pure-tone audiometry screening, and visual acuity was tested with Snellen's letters. Deafness was defined as the need for hearing aids. Mild hearing loss was defined as unilateral or bilateral hearing loss of >25 dB in at least 2 frequencies. Blindness was defined as an absence of light perception. Psychometric testing was performed by 1 of 3 trained research assistants who were unaware of the 20-month outcomes of the ELBW child or whether the child was of ELBW or normal birth weight. The test considered for the purpose of this study was the tetrad Kaufman Assessment Battery for Children (KABC) Mental Processing Composite (MPC), which includes hand movements, triangles, word order, and matrix analogies subtests. The 4 subtests form an MPC characterized in our previous studies as an IQ equivalent.[24,25] This composite has proved sensitive to the cognitive developmental consequences of prematurity.[25] An IQ equivalent of 40 (3 SDs below the mean) was assigned to 9 children who could not be tested, 7 because of severe cerebral palsy and 2 because of severe retardation/autistic-type behavior. Additional measures included assessments of academic achievement,[26] motor skills,[27] and social functioning.[28] At school age, all tests were scored on the basis of the child's postnatal age. The study protocol was reviewed by the institutional review board committee of University Hospitals of Cleveland, and informed consent was obtained from the parents of the children.

Study Design and Statistical Analysis

The 20-month MDI and 8-year MPC scores were compared by using t tests for continuous variables and χ^2 tests for categorical variables. We used cutoff scores of <70 and <85 to identify lower functioning groups. An IQ of <70 is the internationally accepted standard adopted within the World Health Organization definition of mental retardation, and an IQ of <85 (>1 SD below the mean) is associated with mild learning disability and need for special education.[29,30] For the purposes of prediction of later cognitive function, the cohort was divided into those with and without neurosensory abnormalities based on findings at 20 months' CA. Positive and negative predictive values were calculated as proportions for the total population of 200 children and for the subgroups of children diagnosed with and without neurosensory abnormalities at 20 months' CA.

To examine factors related to improvement in cognitive scores from early childhood to school age, children with low MDI scores were divided into groups based on the scores on the MPC at school age. Children with an MDI of <70 were divided into 2 groups: those with an MPC of <70 and those with an MPC of ≥70. Similarly, children with MDI scores of <85 were divided into 2 groups: those with MPC scores of <85, which included those with scores of <70, and those with MPC scores of ≥85. Logistic regression then was used to examine factors associated with the presence or absence of improved cognitive outcomes across the 2 assessments for each of the 2 cutoffs. Two analyses were conducted for each cutoff. The first analysis included major neurosensory abnormality at 20 months' CA as a predictor, and the second included chronic lung disease and a severely abnormal ultrasound as predictors in place of neurosensory impairment. Additional predictors included in both analyses were gender, socioeconomic status (SES), and race. We used the mean of the sample z scores of maternal education and the median family income of the census tract of the family's residence as a measure of SES, because preliminary analyses revealed that of several socioeconomic variables considered, these 2 factors were best in predicting unique variance in child cognitive outcomes. The rationale for examining the effects of chronic lung disease and severe ultrasound abnormality, as well as neurosensory impairment at 20 months' CA, was our interest in identifying both neonatal and postnatal predictors of changes in child cognitive status over time. The fact that chronic lung disease and ultrasound abnormality are potential precursors for neurosensory abnormality justified inclusion of these factors in separate analyses.[1,31]

RESULTS

Comparison of 20-Month and 8-Year Outcomes

Neurosensory Outcomes

The rates of major neurologic abnormality at 20 months' CA and 8 years of age were 19% and 16%, respectively. Eight children who were diagnosed with a major neurologic abnormality at 20 months' CA were considered to be normal at 8 years, whereas 5 other children who were considered normal at 20 months were diagnosed with cerebral palsy at 8 years (Table 2). The rate of hearing loss increased between 20 months' CA and 8 years because of different methods of assessment at these 2 ages.

Cognitive Outcomes

The mean MDI ± SD score was 75.6 ± 16 at 20 months' CA compared with a mean MPC of 87.8 ± 19 at 8 years. The 154 children who were free of major neurosensory abnormality at 20 months' CA had a mean MDI of 79.3 ± 16 compared with a mean MPC of 92.3 ± 15. In comparison, the 176 normal birth weight control children who were of similar sociodemographic background to the ELBW children had a mean MPC of 99.8 ± 15. For children who had major neurosensory abnormality at 20 months' CA, the mean MDI was 63.2 ± 15 compared with a mean MPC of 72.9 ± 2 at 8 years.

Thirty-nine percent of the ELBW children had a 20-month MDI of <70 compared with 16% who had an MPC of <70 at 8 years. Sixty-seven percent vs 37% had scores of <85, respectively (Table 3). Among the neurosensory-normal subgroup, 29% vs 7% had cognitive scores of <70 at 20 months' CA and 8 years, respectively. Eighty percent (36 of 45) of the neurosensory-normal subgroup who had an MDI of <70 at 20 months' CA tested above this range at 8 years. Among those with neurosensory abnormalities, 72% had an MDI of <70 at 20 months, whereas 48% had an MPC of <70 at 8 years. Very few children deteriorated in their scores.

Predictive Validity

Positive and negative predictive values were calculated for 20-month MDI scores of <70 and <85, respectively (Table 4). The positive predictive value (ie, the probability of a child having an MPC of <70

TABLE 2. Children With Diagnoses of Neurosensory Abnormality at 20 Months and 8 Years

	20 mo (N = 200), n (%)	8 y (N = 200), n (%)
Major neurologic abnormality	37 (19)	32 (16)
Cerebral palsy	29 (15)*	31 (16)†
Hypertonia	5 (3)‡	—
Hypotonia	2 (1)§	—
Hydrocephalus‖	1 (0.5)	1 (0.5)
Hearing loss	17 (9)¶	26 (14)#
Blindness	1 (0.5)**	0

* At 8 years, 2 children with diplegia and 1 with hemiplegia were considered normal.
† Three children, considered normal at 20 months, were diagnosed with cerebral palsy at 8 years (2 with hemiplegia and 1 with diplegia).
‡ At 8 years, 4 were considered normal and 1 had diplegia.
§ At 8 years, 1 was considered normal and 1 had hemiplegia.
‖ Shunt-dependent hydrocephalus without other neurosensory abnormality. Five additional children had a shunt (3 with cerebral palsy, 1 hypertonia, and 1 with deafness).
¶ Unilateral or bilateral hearing loss; 10 of these children had hearing aids and 9 children had cerebral palsy, including 1 with a shunt. Four children did not have hearing aids or cerebral palsy; 2 of these children had unilateral hearing loss and 2 had bilateral hearing loss.
# Includes 3 children who had hearing aids; 6 additional children had bilateral hearing and 17 unilateral hearing loss of >25 dB in at least 2 frequencies. Five of the children also had cerebral palsy.
** Also has severe cerebral palsy and was not considered blind at 8 years old.

TABLE 3. Rates of Subnormal (<70), Borderline (70–84), and Normal Cognitive Scores at 20 Months and 8 Years of Age

	Total Population (n = 200): 8-Year MPC				Neurosensory Status at 20 Months							
					Normal (n = 154): 8-Year MPC				Abnormal (n = 46): 8-Year MPC			
20-month MDI	<70	70–84	≥85	Total	<70	70–84	≥85	Total	<70	70–84	≥85	Total
<70	29	21	28	78 (39%)	9	16	20	45 (29%)	20	5	8	33 (72%)
70–84	2	15	39	56 (28%)	1	12	36	49 (32%)	1	3	3	7 (15%)
≥85	1	6	59	66 (33%)	0	5	55	60 (39%)	1	1	4	6 (13%)
Total	32	42	126		10	33	111		22	9	15	
	(16%)	(21%)	(63%)		(7%)	(21%)	(72%)		(48%)	(20%)	(32%)	

TABLE 4. Positive and Negative Predictive Values of the 20-Month MDI for 8-Year Cognitive Functioning

	Total Population (n = 200)	Neurosensory Status at 20 Months	
		Normal (n = 154)	Abnormal (n = 46)
MDI < 70			
Positive predictive value	0.37 (29/78)	0.20 (9/45)	0.61 (20/33)
Negative predictive value	0.98 (119/122)	0.99 (108/109)	0.85 (11/13)
MDI < 85			
Positive predictive value	0.50 (67/134)	0.40 (38/94)	0.73 (29/40)
Negative predictive value	0.89 (59/66)	0.92 (55/60)	0.67 (4/6)

at 8 years given an MDI of <70 at 20 months) was 0.37 (95% confidence interval [CI]: 0.27, 0.49) for the total population of ELBW children, 0.20 (95% CI: 0.10, 0.35) for the neurosensory-intact subgroup, and 0.61 (95% CI: 0.42, 0.77) for the group with neurosensory abnormalities. The negative predictive values (ie, the probability of having an MPC of >70 at 8 years given an MDI of >70 at 20 months) were 0.98 (95% CI: 0.93, 0.99) for the total population and 0.99 (95% CI: 0.95, 0.9998) and 0.85 (95% CI: 0.55, 0.98) for the neurosensory-normal and -abnormal subgroups, respectively. Thus, the predictive validity of a subnormal MDI for subnormal cognitive function at school age was poor when the total ELBW cohort was considered. It was better among the subgroup of children who had neurosensory abnormalities. In contrast, a child who tested normally at 20 months had an excellent chance of testing in the normal range at 8 years.

When a 20-month MDI of <85 was considered, the positive predictive value for an MPC of <85 was 0.50 (95% CI: 0.41, 0.59) for the total population and 0.40 (95% CI: 0.30, 0.51) and 0.73 (95% CI: 0.56, 0.85) for the neurosensory-normal and -abnormal subgroups, respectively. The negative predictive values were 0.89 (95% CI: 0.79. 0.96), 0.92 (95% CI: 0.82, 0.97), and 0.67 (95% CI: 0.23, 0.96), respectively.

Sociodemographic, Birth, and Neonatal Correlates of Change or Stability in Cognitive Scores

Univariate comparisons of maternal sociodemographic, birth, and neonatal data of children who improved in their cognitive scores from 20 months' CA to 8 years and those who remained in the sub-

normal category are presented in Table 5. Children whose MDI scores increased from <70 to MPC scores ≥70 had significantly lower rates of severe cerebral ultrasound abnormality, cerebral palsy, and overall neurosensory abnormality than children with subnormal scores at both time points. These groups did not differ in sociodemographic factors including mean family income, mean percent of families below the poverty level, and maternal race, marital status, and education. Sociodemographic factors did play a role, however, when an initial cognitive score of <85 was considered. Families of children whose scores remained <85 compared with those whose scores increased to ≥85 lived in neighborhoods with a significantly lower family income and higher proportion below the poverty level. Within the neurosensory-normal subgroup, more were black. Children with a severely abnormal cranial ultrasound had a significantly lower rate of improved cognitive outcome than those without this neonatal complication in both the <70 and <85 groups. This was evident even within the neurosensory-intact subgroup. The children with improved outcomes did not differ from those who remained cognitively impaired in the rates of early-intervention services. For children whose MDI was <70 versus an MPC of ≥70, the respective rates of these services were 73% vs 67%, and for those with an MDI of <85 versus an MPC of ≥85, the rates were 69% vs 59%, respectively (data not shown).

Logistic-regression analyses that included SES (the mean of *z* scores of maternal education and median family income), gender, race, and 20-month neurosensory status as covariates revealed that neurosensory abnormality predicted lack of cognitive change from <70 to ≥70 (odds ratio [OR]: 6.9; 95% CI: 2.4, 20.2; $P < .01$). When a cognitive change of <85 to ≥85 was considered, neurosensory abnormality similarly predicted lack of change (OR: 4.8; 95% CI: 2.0, 11.3; $P < .001$), whereas higher SES *z* scores tended to predict improvement, although this difference did not reach statistical significance (OR: 0.65; 95% CI: 0.40,1.1; $P = .09$). When the 2 neonatal risk factors (a severely abnormal cranial ultrasound and chronic lung disease) were included in the regression model, rather than neurosensory abnormality, a severely abnormal cranial ultrasound predicted lack of cognitive change from <70 to ≥70 (OR: 4.8; 95% CI: 1.5,14.9; $P < .01$). Lack of change from <85 to ≥85 was predicted by both a severely abnormal ultrasound (OR: 3.4; 95% CI: 1.3, 8.3; $P < .01$) and lower SES (OR per unit increase in *z* score: 0.53; 95% CI: 0.01, 0.92; $P < .05$). The results were similar when only the neurosensory-intact subgroup of children was considered in this model.

8-Year School-Age Functioning

The children whose cognitive scores remained <70 at 8 years had a mean MPC of 54.7 ± 11 compared with a mean MPC of 87.1 ± 10 for children whose scores improved to ≥70 and a mean MPC of 96.8 ± 13 for those whose scores were consistently ≥70. For the neurosensory-intact subgroup, the mean MPC scores were 61.2 ± 7 vs 85.5 ± 9 and 97.4 ± 13, respectively. Table 6 illustrates that the children whose MDI scores improved from <70 to MPC scores ≥70 had significantly better school-age functioning than children who stayed consistently at <70. This included lower rates of limited academic skills, poor motor skills, poor adaptive functioning, and need for an individual education program. However, even the subgroup of children whose scores improved to ≥70 did less well at school than children who tested consistently >70.

DISCUSSION

Technologic and therapeutic advances in perinatal care necessitate early and valid information concerning the associated long-term and potential iatrogenic effects of such care. The BSID II MDI is the instrument most commonly used to assess the prevalence of subnormal cognitive outcome among ELBW infants.[1–7] Based to a large extent on reported results, many have questioned the current active delivery room care of infants born at the limits of viability.[32,33] We thus sought to determine the predictive validity of a subnormal MDI for school-age cognitive functioning. Our results reveal that a subnormal MDI has a very poor positive predictive validity when based on testing of ELBW infants at 20 months' CA. Among children who were free of neurosensory abnormalities, 80% of those who tested in the subnormal range at 20 months' CA had scores above this level at 8 years, although they did have poorer school-age functioning than children who tested in the normal range at both 20 months and 8 years of age. Evidence of brain injury defined as either a severely abnormal neonatal cranial ultrasound or neurosensory impairment at 20 months' CA predicted stable cognitive deficits at 20 months and 8 years. Although sociodemographic factors did not predict cognitive change for children functioning below the subnormal (<70) range, they were related to lack of cognitive improvement for children with MDI scores of <85, a somewhat broader range of initial impairment.

The BSID II were introduced in 1992 to provide updated normative data because secular increases in cognitive function had occurred since the original scales were published in 1969.[14,34,35] One problem noted within a few years of the introduction of the BSID II was that different scores could be obtained depending on the selection of the starting point of testing and scoring table used for preterm infants.[21–23,36] For example, the starting point for a 13-month-old child born 3 months early would be 10 months when correcting for preterm birth. This child might score more poorly than if testing had started on an item set corresponding to the postnatal or uncorrected age,[22] because starting at the CA may not allow infants to earn points on a higher item set. For example, Gauthier et al[37] found that 37% of infants with a CA of 12 months had an MDI of <85 when testing was started at the 11-month items, compared with 18% who scored in this range when testing was started at the 12-month items and only 3% when testing was started at the 13-month items. Because of these limitations, Nellis and Gridley[36] cautioned that scores on the BSID II be used only as

TABLE 5. Comparison of Maternal Demographic and Infant Data According to Change in Cognitive Scores

	Total Population (n = 200)				Neurosensory-Intact Group (n = 154)			
	MDI < 70		MDI < 85		MDI < 70		MDI < 85	
	MPC < 70 (n = 29)	MPC ≥ 70 (n = 49)	MPC < 85 (n = 67)	MPC ≥ 85 (n = 67)	MDI < 70 (n = 9)	MDI ≥ 70 (n = 36)	MDI < 85 (n = 38)	MPC ≥ 85 (n = 56)
Maternal demographic data*								
Unmarried, n (%)	12 (41)	29 (59)	34 (50)	36 (54)	5 (56)	23 (64)	23 (61)	31 (56)†
Black race, n (%)	20 (69)	35 (71)	47 (70)	41 (61)	8 (89)	8 (78)	31 (82)	35 (63)†
Education, n (%)								
< High school	3 (10)	2 (14)	8 (12)	8 (12)	2 (22)	6 (17)	6 (16)	7 (13)
High school	14 (48)	15 (31)	28 (42)	19 (28)	4 (44)	10 (28)	16 (42)	15 (27)
> High school	12 (41)	27 (55)	31 (46)	40 (60)	3 (33)	20 (56)	16 (42)	34 (61)
Mean percent below poverty level*‡	18 ± 17	21 ± 18	22 ± 19	16 ± 15†	17 ± 10	24 ± 19	25 ± 19	17 ± 16†
Mean family income†§	39 ± 19	36 ± 21	35 ± 18	42 ± 21†	34 ± 8	35 ± 23	30 ± 14	42 ± 21‖
Infant data								
Birth weight, g ± SD	801 ± 128	785 ± 132	789 ± 135	812 ± 131	796 ± 118	804 ± 135	790 ± 133	821 ± 133
Gestational age, wk ± SD	26.4 ± 2	25.9 ± 2	26.2 ± 2	26.2 ± 2	26.2 ± 2	26.3 ± 2	26.2 ± 2	26.5 ± 2
Gender, male, n (%)	16 (55)	24 (49)	33 (49)	31 (46)	3 (33)	20 (56)	17 (45)	26 (46)
Chronic lung disease, n (%)¶	16 (57)	16 (57)	39 (59)	27 (40)†	4 (44)	19 (53)	21 (55)	20 (36)#
Severely abnormal cerebral ultrasound, n (%)**	13 (45)	9 (18)†	24 (36)	12 (18)†	3 (33)	3 (8)†	9 (24)	5 (9)†
Cerebral palsy, n (%)	13 (45)	8 (16)†	21 (31)	5 (8)†				
Neurosensory abnormality, n (%)††	20 (69)	13 (27)‡‡	29 (43)	11 (16)				

* At 8 years old, pertains to biological or adoptive mother in 89% and to other primary caregiver in 11%.
† $P < .05$.
‡ Mean of percent of families below the poverty level according to the 2000 Census tract areas in which the families lived.
§ Mean of median family income in thousands of dollars according to the 2000 Census tract.
¶ Oxygen dependent at 36 weeks' CA.[17]
‖ $P < .01$.
$P = .06$.
** Includes grade III and IV bleed, periventricular leukomalacia, or ventricular dilatation at discharge.
†† Includes cerebral palsy and or unilateral blindness or deafness at 20 months' CA.
‡‡ $P < .001$.

TABLE 6. School-Age Functioning According to Stability or Improvement of Cognitive Scores Between 20 Months and 8 Years

	Total Population			Neurosensory-Intact Subgroup		
	MDI < 70		Always > 70 (n = 119)	MDI > 70		Always > 70 (n = 108)
	MPC < 70 (n = 29)	MPC > 70 (n = 119)		MPC < 70 (n = 9)	MPC ≥ 70 (n = 36)	
Limited academic skills (Woodcock-Johnson skills cluster < 80), n (%)*†‡§	24 (86)†	18 (38)†	12 (10)†	8 (89)‡	14 (39)†‡	8 (7)†
Poor gross motor function (Bruininks-Oserelsky < 30), n (%)‡*	26 (93)†	17 (35)†	9 (8)†	6 (75)‡	8 (23)†‡	4 (4)†
Poor adaptive functioning (Vineland adaptive < 80), n (%)	27 (93)‡	32 (65)‡‖	58 (49)‖	9 (100)§	24 (67)§¶	53 (49)¶
Individual education program, n (%)#	28 (100)†	29 (59)†	23 (20)†	8 (100)§	20 (56)†§	17 (16)†

* The sample was slightly reduced because some children could not be tested.
† $P < .001$.
‡ $P < .01$.
§ $P < .05$.
‖ $P = .05$.
¶ $P = .07$.
# Reported by parent.

general indicators of development and not as immutable information on which to make long-term predictions. The difficulty in testing children with cerebral palsy and its diagnosis during early childhood is also problematic. Children diagnosed with cerebral palsy during infancy or early childhood may not be so diagnosed at school age.[38–42] Similar to our findings, additional cases may also be diagnosed after 2 years of age in very low birth weight (VLBW) populations.[39–41]

In normal populations, measures of cognitive function during infancy are well known to be poor predictors of later IQ.[43–45] Our data suggest that this is also true for many ELBW children. This poor prediction of cognitive function is considered to be because of difficulties inherent in infant testing, measurement error, change in function of the child, and content of the tests with increasing age, individual and inherited patterns of mental development, and environmental influences that become more evident after 2 years of age.[46–48] Aylward[48] noted that 24 months is a critical transition period in cognitive development during which skills in symbolic function, language development, and early concept formation emerge. This finding suggests that the older the child at the time of testing, the predictors of developmental outcomes of ELBW children will be more robust.

Prediction based on infant testing is reported to improve among children with severe handicaps and/or subnormal functioning.[45,49–52] This is in agreement with our findings in the ELBW children with neurosensory abnormalities. Field et al[53] found that increases in IQ in children referred for developmental delay were related to the initial IQ, the clinical diagnosis, and intervention therapy but not to SES. We found an effect of SES in the <85-MDI subgroup but not in the <70-MDI subgroup. This finding is an agreement with the fact that greater biological risk tends to minimize the effects of SES on outcomes.[48,54]

Our findings of the poor predictability of cognitive assessments during early childhood have also been reported for VLBW (<1.5 kg) preterm children born before the 1990s.[55–58] The Victorian Collaborative group in Australia found that 22% of ELBW children tested with the original BSID MDI at 2 years' CA had improved Wechsler Intelligence Scale for Children-Revised IQ scores at 8 years and only 9% deteriorated in function.[55] Improvements in cognitive function were noted in this ELBW group at 5 years of age but not among children with birth weights of 1 to 1.5 kg.[56] Kitchen et al[56] thus concluded that 2-year assessments were often unduly pessimistic and that the ELBW infant requires a longer time to compensate for perinatal and other stresses. Koller et al[57] examined the predictive validity of the 12- and 24-month original BSID MDI for the Wechsler Intelligence Scale for Children IQ score at 5 to 6 years old among VLBW children and found that those whose scores increased between the 2 periods of study had less neonatal illness and neurologic impairment than those whose scores remained stable. Ment et al[58] used the Peabody Picture Vocabulary Test, a measure of receptive verbal abilities, to follow the development of VLBW children and found that 49% of those who had a Peabody Picture Vocabulary Test of <70 at the age of 3 years tested above this level at 11 years of age. Similar findings were noted concerning changes in IQ. Improvement was related to social factors and early intervention. However, children who had early-onset intraventricular hemorrhage and subsequent brain injury tended to deteriorate in function. Among infants with congenital heart disease who underwent open heart surgery, McGrath et al[59] also recently reported the poor positive predictive validity of the original BSID at 1 year of age for intelligence at 8 years. Similar to our results, there was a good negative predictive value in that children who functioned in the normal range at the age of 1 year continued to do so at age 8 years of age.

Animal studies suggest that plasticity in neurodevelopment is highest before synaptic stabilization, which occurs during early to middle childhood.[60] This, together with the methodologic issues related to BSID II, may explain the improvements in cognitive function during childhood that we and others have described. However, severe ultrasound abnor-

mality and neurologic impairment indicate more severe brain injury and thus less potential for recovery.

CONCLUSIONS

Attainment of a subnormal MDI on the BSID II at 20 months' CA is not predictive of subnormal cognitive function at school age, although it is better for children who have neurosensory impairments. However, it may be a marker of future risk of problems in academic, motor, and social functioning and for increased need for special education. We are concerned that subnormal cognitive outcomes that are included in the definition of neurodevelopmental impairment for reporting of outcomes of ELBW children and used to make critical decisions concerning delivery room care based on their presumptive but limited predictive validity may be misleading to caregivers and parents. Based on our results and those of others, results of the Bayley Scales of Infant Development or similar cognitive assessments should not be used to make decisions about medical treatment or policy, especially those as important as the life and death of ELBW infants. We suggest that the data used for reporting early childhood outcomes of infants born at the limits of viability be based mainly on the rates of children with neurosensory impairment who also have cognitive deficits rather than on cognitive outcomes per se.

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EVIDENCE-BASED MEDICINE AND THE SEARCH FOR A SCIENCE OF CLINICAL CARE BY JEANNE DALY (BERKELEY, CA: UNIVERSITY OF CALIFORNIA PRESS; 2005) ISBN 0-520-24316-1

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Jerold Lucey, MD

Poor Predictive Validity of the Bayley Scales of Infant Development for Cognitive Function of Extremely Low Birth Weight Children at School Age

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