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CASE STUDY

Neurodevelopmental outcome for extended cold water drowning: A longitudinal case study

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Abstract

There is little longitudinal data examining outcome of pediatric near-drowning. Most literature tracks status 5 years or less post insult, focusing primarily on gross neurologic status as opposed to more subtle neurocognitive deficits. The present case tracks the neuropsychological profile of a child who was submerged for 66 min, the longest time documented. Acute medical support was aggressive, and recovery was dramatic, being featured in multiple media reports. Although an article published 6 years after the near-drowning described the child as "recovering completely," the longitudinal profile indicates a pronounced pattern of broad cognitive difficulties, particularly notable for global memory impairment. Neuropsychological test results were significant despite the fact that the patient's recent MRI and MEG were within normal limits. This case demonstrates the need for long-term neuropsychological follow-up of pediatric patients with histories of neurologic injury, as gross neurological examination and MRI and MEG scans may not reveal underlying brain dysfunction. (*JINS*, 2002, *8*, 588–595.)

Keywords: Near-drowning, Neurodevelopment, Pediatric brain injury, Anoxia

INTRODUCTION

Aquatic accidents are a leading cause of morbidity and mortality in children (Hedberg et al., 1990; Kallas & O'Rourke, 1993; Kyriacou et al., 1994). For children younger than 5, drowning is the third leading cause of accidental death, while for teenagers, it is second only to motor vehicle accidents (Bureau of Census, 1982). *Near-drowning* is defined as "survival following asphyxia due to submersion" (Brooks, 1988). There has been considerable interest in identifying predictive and protective factors in outcome. Hypotheses of neuroprotection include the release of excitatory amino acids, metabolic slowing, and the stabilization of cerebral edema (Huckabee et al., 1996). Hypothermia has also been a particularly prominent factor, as outcomes are generally more positive (Biggart & Bohn, 1990) and may be particularly important for pediatric patients.

Children in particular are susceptible to rapid cooling in water due to relatively little subcutaneous insulation and a large surface area:body weight ratio (Kallas & O'Rourke, 1993; Karhunen & Cozantis, 1983). As the core temperature falls below 32° C, pulse and respiration rates decrease, reducing metabolic consequences for insult ("Immersion and Drowning . . .," 1977).[a] A retrospective review of 55 near-drowning pediatric cases suggested that a detectable pulse or heart beat at the first medical facility was a correlate of relatively intact neurologic recovery. The exception was for patients with hypothermia, as they may arrive to the emergency room apneic and pulseless but later experience remarkable recoveries (Biggart & Bohn, 1990).

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Although hypothermia may improve prognosis, accidental near-drowning is different from induced hypothermia due to the lack of pre-oxygenation, cardioplegia, and careful monitoring (Orlowski, 1988). CT studies suggest that near-drowning survivors are not physiologically homogenous but display a variety of cerebral changes, ranging from hemorrhagic infarctions to global atrophy (Fitch et al., 1985). There is also a wide spectrum of outcome for pediatric near-drowning victims, ranging from persistent vegetative states to perceived "total" recovery. MRI studies indicate that injury to various structures may relate to the stage of pediatric brain maturity (e.g., myelination, location of amino acid receptors) (Dubowitz et al., 1998). For example, the unmyelinated newborn brain may be more susceptible to necrosis, resulting in higher incidence of laminar cell death in infants than in older children.

Factors that determine survival with minimal neurologic deficit are not yet clear, but likely in part relate to cardiovascular status (Habib et al., 1996). The recent development of a physiologic scoring scale (e.g., Pediatrics Risk of Mortality System) to predict "intact" survival illustrates the relative focus on acute neurologic status and gross physiologic outcome (Zuckerman et al., 1998). Separating children who survive relatively intact from those who die or sustain significant neurodevelopmental disruption has, however, proven difficult with clinical and radiologic studies (Romano et al., 1993).

As resuscitation techniques improve, there are likely to be more survivors who have sustained neurologic insult. Most available research focuses on gross neurologic outcome, as opposed to more subtle neuropsychological deficits. Pediatric victims are typically described as forming a bimodal distribution (e.g., severely impaired *vs*. seemingly spared; Kemp & Sibert, 1991; Pearn et al., 1979). Statistical probability would instead, however, suggest a bell-curve distribution, given the variety of individual differences and general applicability of normal distribution to a variety of mental and physical traits (Minium, 1978).

As noted above, there are several reports that present recovery without clear neurologic deficit (Bell et al., 1985; Pearn, 1977; Siebke et al., 1975). However, in these cases, there is no longitudinal follow-up to track neurocognitive development into adolescence and early adulthood. Neural networks associated with more subtle forms of intellectual activity may be among the first affected in immersion incidents (Pearn, 1977). Currently, however, there is a relative absence of longitudinal neuropsychological data examining the wide spectrum of cognitive abilities for these children.

To address the lack of longitudinal research on neuropsychological outcome, the present paper reports the case of a 14-year-old girl who at age $2\frac{1}{2}$ was submerged in frigid water for 66 min. This patient's recovery has been documented as the longest time ever reported for "good neurologic recovery" (Bolte et al., 1988). This child was also subsequently described as "recovering completely" (Mecklinger et al., 1998). She currently displays, however, a broad pattern of neurodevelopmental compromise and impaired memory function, demonstrating the need for longitudinal monitoring and intervention for all critical pediatric near-drowning cases.

CASE REPORT

R.D. is the product of a full-term, unremarkable pregnancy and delivery, weighing 7 pounds, 6 ounces at birth with no perinatal complications. No family history of learning disability, behavioral disorder, or psychiatric disorder was reported. Both parents have obtained college degrees, and R.D.'s siblings are characterized as very bright students who display no academic difficulties. R.D. was reported to be a content, even-tempered baby and toddler. No behavioral, neurologic, or early cognitive problems were noted prior to the accident. Developmental milestones were age-appropriate until the time of the near-drowning at age $2\frac{1}{2}$.

On June 10, 1986, R.D., then a $2\frac{1}{2}$-year-old girl, fell into an icy stream swollen from a melting mountain snow pack. Her brother saw her fall into the water and immediately told his mother. After searching for her for approximately 4 to 10 min, rescue personnel were called and arrived within 8 min. Emergency workers found her wedged against a rock with no evidence of an air pocket. They removed her from the water 62 min after the initial call. R.D. was cyanotic, apneic, and flaccid with fixed, dilated pupils and no palpable pulse (Glasgow Coma Score = 3). Cardiac monitoring revealed asystole, and rescue workers initiated CPR. The child felt cold to touch, but her temperature was not immediately measured. The day after the accident, the water temperature was measured to be 5° C (40° F).

The child was intubated, and as asystole persisted, external cardiac chest compressions were ongoing. R.D. was then transferred via Life Flight to the nearby pediatric hospital where extracorporeal rewarming (ECR) was administered due to extreme hypothermia and ongoing cardiac arrest. Core temperature at the initiation of the procedure was 19° C. Approximately 3 hr had passed since the submersion. External chest compressions were discontinued, and a warming gradient of 10° C was maintained between the perfusate and core body temperature until the perfusate temperature reached 38° C. When the nasopharyngeal temperature climbed to 25° C, a single spontaneous gasp and fine ventricular fibrillation occurred. A few minutes later, the patient opened her eyes, and her pupils became reactive. Cardiac rhythm changed to coarse ventricular fibrillation and then to normal sinus rhythm. When core temperature reached 37° C, ECR was discontinued. Total bypass time was 53 min.

Due to the development of a left occipital scalp hematoma during ECR, a CT scan was obtained, revealing a minor amount of subarachnoid blood along the superior falx but no evidence of parenchymal abnormality. It is difficult to ascertain the contribution of the head injury to this child's later presentation, but at the time of her hospitalization, treating physicians did not judge the head trauma to be of significant consequence. Postoperatively, barbiturate coma was not used, but phenobarbital sodium was given for seizure prophylaxis, and no seizure activity was noted. Neither controlled hypothermia nor intracranial monitoring was used after the completion of ECR. Severe noncardiogenic pulmonary edema developed, requiring 6 days of mechanical ventilation. Other complications during R.D.'s hospital course included an intra-abdominal abscess secondary to perforation of the small bowel, a non-displaced tibial fracture, and a mild case of cutaneous varicella. She also sustained cortical blindness for approximately 7 weeks following the accident, but this problem resolved without apparent residual symptoms.

R.D.'s neurologic course showed gradual but steady improvement during her 8-week hospitalization. At discharge, her receptive and expressive language skills were described as "age-appropriate," as were her fine motor skills. One year following the accident, her fine motor tremor had progressively improved, and at age $3\frac{1}{2}$, R.D. was functioning at a level consistent with age-expectations. R.D. achieved gross neurologic recovery and subsequently entered Kindergarten without the need for special education support at that time.

As previously noted, R.D.'s submersion in cold water for an estimated 66 min was the longest submersion time documented in the pediatric or adult literature. In addition, 19° C was the lowest reported temperature recorded in a submersion victim who achieved intact gross neurologic function. Almost 13 years have now elapsed since the near-drowning accident. R.D. was first identified for Special Education support when she was in the first grade. At age 14, she is currently said to be struggling academically and displays many neurodevelopmental sequelae typical of traumatic brain injury. In addition to visual–spatial and perceptual–motor deficits, she displays significant memory impairment and attentional difficulties. In sum, the results of neuropsychological testing reflect long-term sequelae that are clinically significant.

METHOD

Neuropsychological testing was administered several times during the last 8 years (1990, age 6 years, 11 months; 1995, age 11 years, 4 months; and 1998, age 14 years, 6 months). All testing was administered by an experienced neuropsychometrician under the direct supervision of the examiner. Standardized testing and scoring procedures were strictly followed. A summary of the test results is provided in Tables 1 to 6. In addition, an MRI scan was obtained in June 1998, 12 years following the accident. In November 1998, magneto-encephalography (MEG) data were also acquired using a 122-channel biomagnetometer. Finally, due to the patient's history of post-submersion cortical blindness, an ophthalmological examination was conducted in April 1999.

RESULTS

Global Intelligence

Over the last 8 years, R.D.'s I.Q. scores have been generally consistent but constitute an uneven profile of mild to severe cognitive deficits. It should be noted that due to the length of time over which she was evaluated, the WISC–R was used for the first evaluation and then the WISC–III was used for the second and third testing sessions. According to the WISC–III manual (Wechsler, 1991), Full Scale I.Q. scores average about 5 points lower on the WISC–III than on the WISC–R in normal samples and about 6 points lower in clinical samples. The difference between Performance I.Q. scores in the two instruments tends to be larger than the difference in Verbal I.Q. scores in normal samples (7 *vs.* 2 points) but approximately the same in clinical samples (approximately 5 points). Given these findings, R.D.'s I.Q. scores over the years have remained relatively stable.

Table 1. Intelligence test results

	Dates of testing		
Score	9/90[1]	2/95[2a]	5/98[2b]
Verbal subtests			
Information	11	8	9
Similarities	14	12	10
Arithmetic	9	5	6
Vocabulary	5	12	10
Comprehension	9	9	7
Digit Span	7	7	4
Performance subtests			
Picture Completion	8	9	8
Coding	4	3	3
Picture Arrangement	9	6	7
Block Design	10	7	8
Object Assembly	7	8	9
I.Q. scores			
Verbal I.Q.	97	95	91
Performance I.Q.	84	79	81
Full Scale I.Q.	89	86	85
WISC–III Index Scores			
Verbal Comprehension		102	95
Perceptual Organization		86	89
Freedom From Distractibility		78	72
Processing Speed		77	n/a

Note. Subtest mean = 10 (3); I.Q. mean = 100 (15).
[1] Wechsler Intelligence Scale for Children–Revised; age 6-11.
[2] Wechsler Intelligence Scale for Children–III; ages 11-4[a], 14-6[b].

Most recently, R.D. obtained a WISC–III Full Scale I.Q. score of 85, placing her in the Low Average range of intellectual ability. She obtained a Verbal I.Q. of 91, which is at the lower limit of the Average range, and a Performance I.Q. of 81, which is near the lower limit of the Low Average range. Her scores on the Arithmetic, Comprehension, Digit Span, and Picture Arrangement subtests were below average for her age group (≤16th percentile). It also was noted that her score on Coding has remained markedly deficient (≤2nd percentile), suggesting inefficient visual language processing and perceptual-motor deficits.

Table 2. Sensory–motor testing

Test	9/90[1]	2/95[2]	5/98[3]
Grip Strength			
Dominant (R)	13.67 kg	23.33 kg	27.3 kg
Age mean	9.05 (2.50)	23.65 (5.36)	28.30 (2.98)
z score	+1.85	−0.06	−0.33
Nondominant (L)	11.33 kg	18.33 kg	23.6 kg
Age mean	7.90 (2.34)	19.10 (5.04)	25.65 (4.30)
z score	+1.47	−0.15	−0.48
Finger Oscillation Test			
Dominant (R)	25.8	33.2	36.2
Age mean	33.1 (4.1)	40.9 (4.8)	44.7 (4.8)
z score	−1.78	−1.60	−1.77
Nondominant (L)	18.8	26.0	27.6
Age mean	30.1 (3.4)	36.5 (4.7)	39.3 (4.9)
z score	−3.32	−2.23	−2.39
Grooved Pegboard Test			
Dominant (R)	—	95 s	89 s
Age mean	—	68.82 (8.2)	64.57 (11.0)
z score	—	+3.19	+2.22
Nondominant (L)	—	126 s	122 s
Age mean	—	71.64 (10.8)	66.00 (8.2)
z score	—	+5.03	+6.83
Tactual Performance Test (6 blocks)			
Dominant (R)	—	3.38 min	2.17 min
Age mean	—	3.0 (1.3)	2.4 (1.0)
z score	—	+0.29	−0.23
Nondominant (L)	—	4.57 min	1.32 min
Age mean	—	2.4 (0.9)	1.8 (0.5)
z score	—	+2.41	−0.96
Both hands	—	2.83 min	1.18 min
Age mean	—	1.2 (0.5)	1.1 (0.3)
z score	—	+3.26	+0.27
Total time	—	10.78 min	4.72 min
Age mean	—	6.6 (2.3)	5.1 (1.0)
z score	—	+1.82	−0.38
Block memory	—	4/6	3/6
Age mean	—	4.4 (1.1)	4.5 (1.2)
z score	—	−0.36	−1.25
Location memory	—	3/6	2/6
Age mean	—	3.1 (1.4)	3.4 (1.2)
z score	—	−0.07	−1.17

Note. [1]age 6-11; [2]age 11-4; [3]age 14-6.

Sensory–Motor Function

R.D. displayed no obvious difficulty for visual or auditory acuity. Tactual sensory–motor integration was intact. She is predominantly right-handed, although she used her left hand occasionally during the Lateral Dominance Examination, suggesting some mixed dominance for upper extremities. She also displayed mixed dominance for the lower extremities. Grip strength was age-appropriate bilaterally, but there was evidence of mild left-sided weakness, consistent with previous examination. She had significant bilateral difficulty for fine motor control and dexterity. There was some unsteadiness of right-handed intentional movement, being somewhat slow and tremulous. Handwriting was slow bilaterally, and cursive writing was particularly inefficient.

Table 3. Language and achievement testing

Score	9/90[1]	2/95[2]	5/98[3]
WRAT			
Reading	82	82	83
Spelling	84	72	84
Arithmetic	73	71	82
Picture Peabody Vocabulary Test–Revised			
Standard score	100	105	114
Percentile rank	50th	63rd	82nd

Note. [1]WRAT–R, age 6-11; [2]WRAT–3, age 11-4; [3]WRAT–3, age 14-6. WRAT–R and WRAT–3: $M = 100$, $SD = 15$.

Language

R.D. has significant variability in her language-related skills. Her Verbal subtests ranged from a high of 10 (Similarities, Vocabulary) to a low of 4 (Digit Span). She struggled to a greater degree with expressive language, as opposed to receptive skills. R.D. displayed mild dyslexic characteristics, as she demonstrated significant difficulty processing visual language symbols and her spelling was a relative weakness

Table 4. Memory and learning testing (WRAT–R and WRAT–3)

Test	9/90[1]	2/95[2]	5/98[3]
Verbal memory subtests			
Story Memory	—	3	5
Sentence Memory	—	4	7
Number/Letter Memory	—	7	6
Visual memory subtests			
Picture Memory	—	7	7
Design Memory	—	2	2
Finger Windows	—	5	5
Learning subtests			
Verbal Learning	—	3	4
Sound/Symbol Learning	—	5	4
Visual Learning	—	6	6
Index scores			
Verbal Memory Index	—	66	74
Visual Memory Index	—	63	63
Learning Index	—	64	57
General Memory Index	—	57	58

Note. Subtest mean = 10 (3). [1]WRAT–R, 6-11; [2]WRAT–3, age 11-4, [3]WRAT–3, age 14-1. WRAT–R and WRAT–3: $M = 100$, $SD = 15$.

Table 5. Executive function testing

Test	Dates of testing 9/90[1]	 2/95[2]	 5/98[3]
Trail Making Test			
Part A:			
Time (s)	—	29	25
Age mean	—	18.0 (6.6)	13.0 (2.3)
z score	—	+1.67	+5.22
Errors	—	0	0
Part B:			
Time (s)	—	47	33
Age mean	—	40.6 (11.8)	25.0 (14.6)
z score	—	+0.54	+0.55
Errors	—	0	0
Wisconsin Card Sorting Test			
Categories achieved	—	2	6
Correct responses	—	39	105
Perseverative errors	—	41	11
Age mean	—	18.8 (10.5)	11.8 (7.4)
z score	—	+2.12	−0.11
Non-perseverative errors	—	48	12
Age mean	—	19.1 (12.4)	12.3 (9.4)
z score	—	+2.32	−0.03

Note. [1]Age 6-11; [2]age 11-4; [3]age 14-6.

(e.g., 14th percentile). Graphomotor skills are adequate, although somewhat slow bilaterally.

Visual–Spatial Function

R.D.'s overall visual–spatial abilities are generally impaired. Her recent WISC–III Performance I.Q. of 81 placed her at the 10th percentile. Drawing samples indicate difficulty with perceptual analysis and spatial planning. Her copy of a complex geometric figure (see Figures 1–3) indicated a piecemeal fragmented approach resulting in significant inaccuracy. Her sequential organization of the material was poor, demonstrating constructional dyspraxia evident in previous evaluations.

Table 6. Denman Scaled Scores of the Rey-Osterrieth Complex Figure

Measure	Dates of testing 9/90[1]	 2/95[2]	 5/98[3]
Copy	—	1	2
Immediate	—	6	4
Delay	—	6	4

Note. [1]Age 6-11; [2]age 11-4; [3]age 14-6.

Memory and Learning

R.D. displays dramatic memory impairment. Immediate rote auditory memory was poor for digits (2nd percentile), sentences (16th percentile), and stories (5th percentile). For the Wide Range Assessment of Memory and Learning (WRAML), her General Memory Index was in the severely impaired range (0.6th percentile). Her Verbal (4th percentile) and Visual (1st percentile) Memory scores both reveal marked deficits. In addition, her Learning Index score (0.5th percentile) demonstrated flat learning curves with poor retention. Performance did not significantly improve for cued recall. Her general fund of knowledge was relatively intact (37th percentile) compared to her learning of new information.

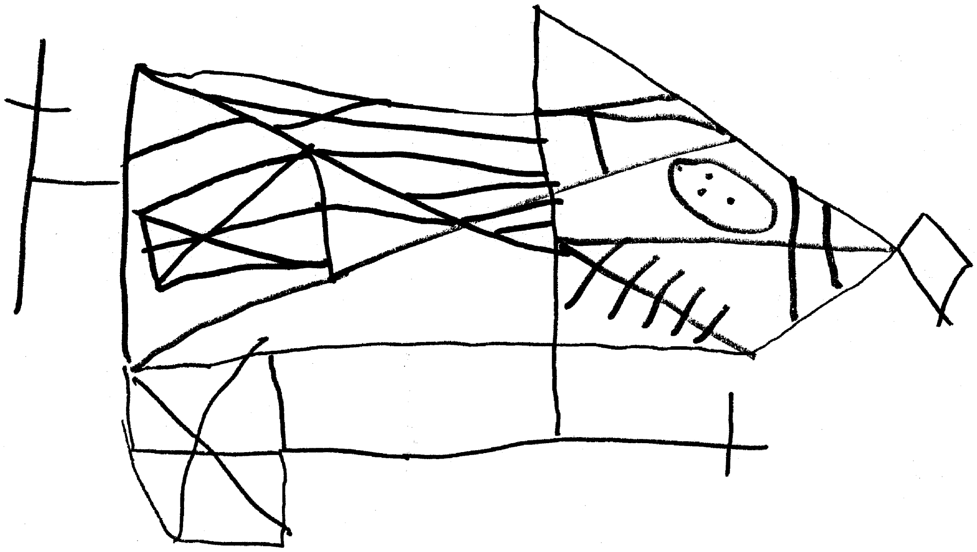

Fig. 1. Copy of Rey-Osterrieth Complex Figure, May 1998, Patient Age 14-6.

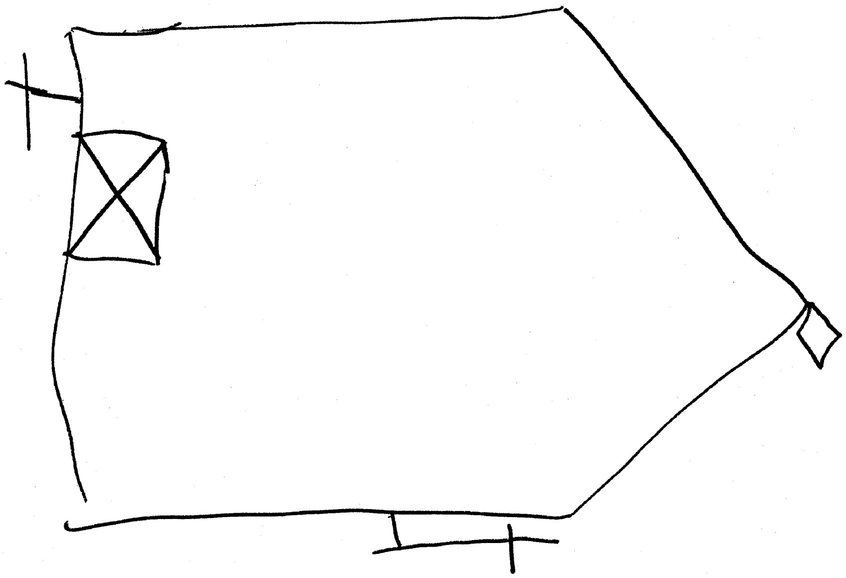

Fig. 2. Immediate Recall of Rey-Osterrieth Complex Figure, May 1998, Patient Age 14-6.

Executive Function

Although R.D. demonstrated adequate problem-solving, she displayed unusual impulsivity. Her performance was poor on a measure of sustained attention, producing an unusual number of omission errors and commission errors on the Connors' Continuous Performance Test, indicating impulsive responding and poor concentration. She also displayed marked difficulty with sequential planning and organization. Some of her test performances, however, improved over time, such as her *z* scores for errors made on the Wisconsin Card Sorting Test. Research on test–retest reliability for children suggests that due to practice effects, retesting should be interpreted with considerable caution (Heaton et al., 1993). As such, it is difficult to assess to what degree R.D.'s improved scores on the WCST represent practice effects *versus* improved problem-solving.

Neurobehavioral Factors

Neurobehavioral factors were assessed by history, parent report, direct observations during the evaluation process, behavior checklists, and psychological tests. R.D. has a

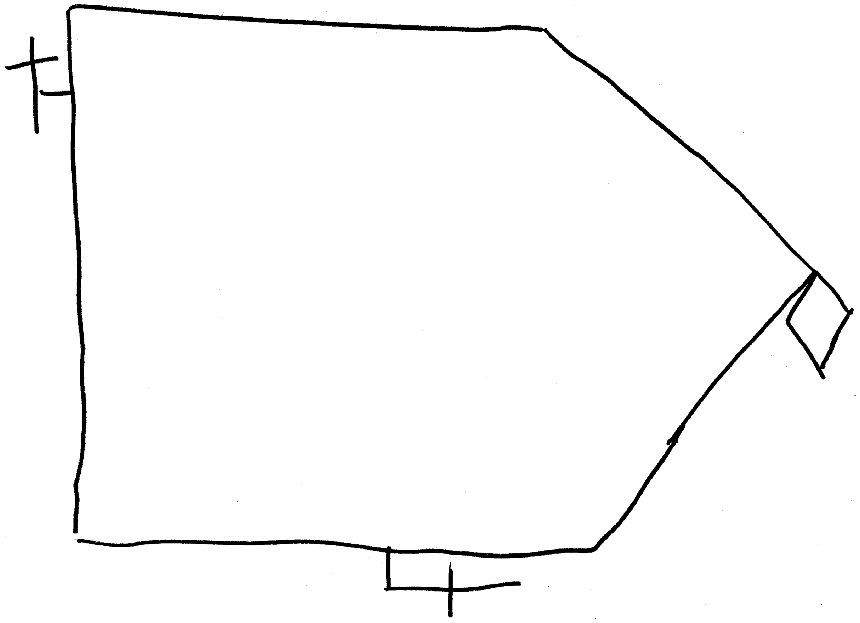

Fig. 3. Delayed Recall of Rey-Osterrieth Complex Figure, May 1998, Patient Age 14-6.

history of being well behaved and pleasant, displaying surprisingly intact social skills. She herself has readily admitted that she sometimes needs to observe her friends closely to obtain cues for appropriate behavior. She did not display significant emotional volatility or reactivity in the context of testing. On self-report questionnaires, she denied any significant anxiety or depressive symptoms. Her completion of the Millon Adolescent Personality Inventory (MAPI) suggested no distinctive psychopathology. Parents describe her as displaying occasional impulsivity and short-sightedness, as well as periodic irritability.

MRI Results

A nonsedation brain MRI without contrast was obtained in June 1998, 12 years after the near-drowning. There was no evidence of focal mass lesion, mass effect, or intracranial hemorrhage. No abnormal extra-axial fluid collections were identified. Overall, the scan was determined to be within normal limits, although a mild degree of atrophy could not be excluded.

MEG Results

Ten minutes of data were collected while the subject sat quietly with eyes closed. Data were analyzed for epileptiform discharges, as well as focal and diffuse slowing. Auditory functioning was assessed using a response reduction paradigm in which a train of stimuli was presented with interstimulus intervals (ISI) of 4, 2, 1, and 0.5 s, and an intertrain interval of 8 s. Analysis examined response latency, amplitude, morphology, topography and source location. Data were also evaluated for appropriate amplitude reductions with decreasing ISI. Language function was assessed using a dichotic listening task. R.D. listened to pairs of different words, given simultaneously, one in each ear. She was asked to determine if the words were semantically related. Data were evaluated for auditory reactivity and the amplitude of the long latency language evoked field.

Spectral analysis of the spontaneous data recorded during quiet rest showed a normal power distribution. Visual inspection of the data confirmed that there was no significant slowing of the background activity and no epileptiform activity. Responses during the auditory response reduction task and the dichotic task could not be interpreted due to extensive movement artifact. Taken together, results of cranial magnetic source imaging were read to be within normal limits.

Ophthalmologic Examination

In April 1999, visual acuity was 20/15 −1 right, 20/30 +1 left. Ishihara testing was normal. Pupil reacted briskly without afferent defect. There was no nystagmus. Visual fields were full. Motility assessment showed full ductions and versions with straight eyes at distance and near. Fundus examination revealed healthy-appearing optic nerves. Clinical impression was mild anisometropia unrelated to the accident.

DISCUSSION

The present case documents the cognitive development of a pediatric patient who was initially presented in the literature as "recovering completely" and demonstrates the importance of longitudinal neuropsychological monitoring to assess outcome. Thirteen years following the injury, R.D. displays many neurocognitive sequelae typical of brain injury secondary to cerebral ischemia. Although she sustained some mild head trauma, this injury was not judged to be of significant consequence at the time of her hospitalization.

Testing revealed impaired verbal and visual memory consistent with global memory impairment, and R.D. displayed flat learning curves with poor retention over time. Cuing in a recognition format did not substantially improve her performance, suggesting significant encoding deficits. Although there is also clinical evidence of attention problems, poor concentration cannot alone account for the magnitude of memory impairment. There is increasing evidence that transient global ischemia frequently causes significant memory deficits (Mecklinger et al., 1998). The notion that there is a selective deficit in explicit memory functions is supported by other case studies (Corneli, 1992; Zola-Morgan et al., 1986).

Academic testing also indicates that R.D. is behind her age-matched peers on basic skills, such as written arithmetic, spelling, and reading. In addition to poor retention of new material, she displays visual–spatial deficits, mild dyslexic qualities, and inefficient graphomotor skills that further complicate her ability to keep up with academic demands. Attentional and planning difficulties also impede her performance.

Although the issue of plasticity has been central to conceptualizing the pediatric nervous system, there is evidence that patients with early hypoxic injury experience some global atrophy (Mecklinger et al., 1998). While the recent MRI did not provide marked evidence of neurological changes, the neuropsychological testing has repeatedly identified areas of significant functional deficits, indicating a pronounced pattern of global neurodevelopmental disruption.

Although pediatric near-drowning patients may have grossly intact neurologic examinations, this case demonstrates the need for long-term follow-up. The toddler and preschool group represents approximately 77% of all childhood near-drowning cases (Zola-Morgan et al., 1986), yet many of the long-term cognitive sequelae may not become readily apparent until early adolescence. Once children enter junior high school, the demands for speeded processing, memory, and organizational skills increases dramatically. Continued contact with patients is essential to anticipate and identify difficulties early such that appropriate neurodevelopmental support can be provided quickly and cost-efficiently. Simply put, children who function well at age 3 may encounter marked difficulties as developmental demands change. Longitudinal tracking and intervention is critical for both patient quality-of-life and a more complete understanding of the limitations of brain plasticity.

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