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Intelligence two years after epilepsy surgery in children ☆

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ABSTRACT

Intelligence before and two years after epilepsy surgery was assessed in 94 children and adolescents and related to preoperative IQ and seizure outcome. The median full-scale IQ was 70 before and two years after surgery. The proportion with a higher or unchanged postoperative IQ was 24 of 49 (49%) of those with an IQ of 70 and more before surgery, nine of 17 (53%) of those with an IQ of 50–69, and ten of 28 (36%) of those with an IQ of less than 50. A significant difference was found between the 47 individuals who became seizure-free and the 47 with persisting seizures, as 60% of the seizure-free children had a higher or unchanged IQ compared with 32% of the 47 who were not seizure-free. The cognitive outcome of children with intellectual disabilities was as good as that of children with average IQ. Thus, they should not be excluded from epilepsy surgery on the basis of low intellectual level.

1. Introduction

Drug-resistant epilepsy may have a severe impact on a child's psychosocial adjustment and behavior, and the long-term effects of seizures may affect children's cognitive development in a negative way [1–4]. Early epilepsy surgery has the potential to reduce or even prevent a cognitive decline [5,6]. Intellectual disabilities are common in children with medically intractable epilepsy [4], and these children have been shown to have a postoperative seizure outcome similar to that of patients with an average intelligence quotient (IQ) [7,8]. As a result, a low IQ should not be a reason for questioning a patient as a possible surgery candidate. Furthermore, a better outcome after surgery can be expected in patients operated on at a younger age and with a shorter duration of epilepsy [9]. Most studies have reported on seizure outcome after specific surgical procedures, such as temporal lobe resection [10,11] or hemispherectomy [12–14]. As clinicians, we meet children with medically intractable epilepsy and intellectual disabilities, but there are relatively few studies describing the cognitive outcome in unselected children with epilepsy severe enough to justify neurosurgery of any type, especially for the subgroup of children with a low IQ [6,9,15]. Such an approach could help in the clinical setting with an unselected group of children with medically intractable epilepsy.

The aim of this study was therefore to to evaluate cognitive functions before and two years after surgery in a consecutive series of pediatric patients. Specific objectives were to relate cognitive effects to seizure outcome and type of surgery and to explore the effect on IQ in children with a low preoperative IQ.

2. Patients and methods

One hundred and ten children and adolescents underwent epilepsy surgery between 1987 and 2006 at Sahlgrenska University Hospital in Gothenburg and had a structured two-year follow-up. Medical data and outcomes have been presented in a recent paper [16]. Ninety-four of them, 48 (51%) females and 46 males, aged eleven months to 18.7 years, had complete pre- and postoperative assessments of intelligence. Nine children, most of them with a severe or profound learning disability, were not formally tested, three children from other Scandinavian countries did not have a neuropsychological follow-up in Gothenburg, one child was lost to follow-up, and two more children were assessed only with the verbal part and one only with the performance part of the Wechsler Intelligence Scale for Children (WISC). These 16 children were not included in this study.

Resections were performed in 83 (88%) of the 94 children and adolescents: in the temporal lobe in 31, in the frontal lobe in 20, in the parietal lobe in seven, in the occipital lobe in three, multilobe resection in 12, and hemispherectomy in ten children. Forty-three of the 83 resections were performed in the right hemisphere and 40 in the left. Eleven children (12%) had nonresective surgery: seven callosotomies, two disconnections of hypothalamic hamartomas, and two multiple subpial transections (MST). The age at operation,

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duration of epilepsy, gender, and type and side of surgery are presented in Table 1.

The individual's level of functioning and mental age rather than the chronological age were taken into consideration when choosing the method for assessing intelligence or developmental level in learning-disabled children. When an age-appropriate test instrument could not be used, a developmental quotient (DQ) or IQ equivalent was calculated (mental age / chronological age × 100). Hereinafter, IQ will consistently be used to represent DQ/IQ. The Swedish versions of the following tests were used: the Griffiths' Developmental Scales, WPPSI-R, WISC or WISC-III, and WAIS-R. The Raven Coloured Progressive Matrices (RCPM), together with the Speedy Performance Test of Intelligence (SPIQ I and II), were used to measure nonverbal and verbal intelligence in four children in the early years of the study period. A full-scale intelligence quotient (IQ) of >69 was considered to be within the normal range, an IQ of 50–69 was regarded as a mild intellectual disability, and an IQ of <50 was regarded as a moderate-to-severe intellectual disability [17].

2.1. Statistical methods

The median, quartiles (Q_1; Q_3), and range were used to describe intelligence quotients. Distributions of individual changes in full-scale IQ, verbal IQ, and performance IQ between pre- and postoperative assessments, respectively, were described using scatterplots. The Wilcoxon–Mann–Whitney test was used to compare the distributions of changes in full-scale IQ, verbal IQ, and performance IQ two years after surgery between the groups of seizure-free and nonseizure-free children. The difference in the proportion of children and adolescents with a higher or unchanged IQ between the seizure-free group and the nonseizure-free group was analyzed with the chi-square test with Yates' correction for continuity. The 95% confidence interval (95% CI) according to Wilson for the difference in proportions between the two groups was also calculated [18]. A p-value of less than 5% after Holm's sequential correction for multiple tests was regarded as significant. Calculations were performed by software provided by Altman [19].

3. Ethics

According to the Swedish National Board of Health and Welfare, clinicians are obliged to secure the quality of care by performing and reporting the results of clinical studies in everyday practice. Approval from an internal review board is not required for this type of research. All participants or caregivers gave their informed consent to participate in this follow-up. Participants and all data have been handled according to the Helsinki Convention.

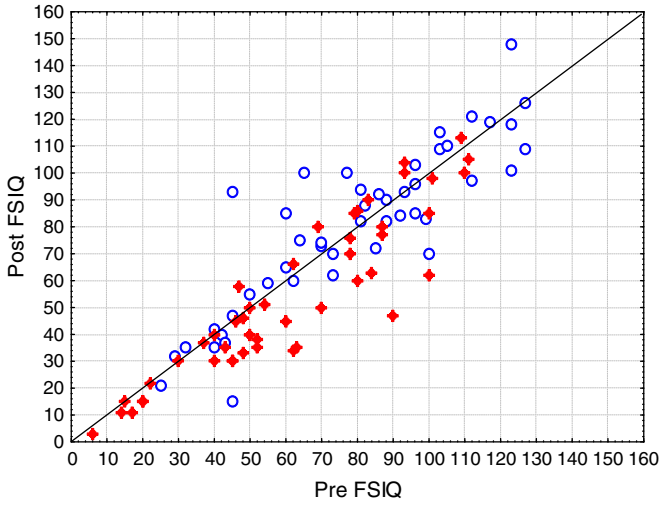

Fig. 1. The pre- versus postoperative full-scale IQ (FSIQ) in 47 seizure-free (circles) and 47 nonseizure-free (crosses) children and adolescents. The median (and quartile) change in FSIQ for the seizure-free group was 2 (−6, 6), whereas it was −5 (−15, 0) for the nonseizure-free group.

4. Results

The distributions of individual changes in full-scale IQ, verbal IQ, and performance IQ are shown in Figs. 1–3. Higher or unchanged full-scale IQ and verbal IQ scores two years after surgery were recorded in 43 (46%) of the 94 children, while 51 (54%) had a higher or unchanged performance IQ (see Figs. 1–3 and Table 2). The median full-scale IQ in the 94 children and adolescents was 70 both before surgery and at the two-year follow-up but with slightly different distributions (Q_1 45; Q_3 93, range: 6–127 and Q_1 38; Q_3 93, range: 3–148, respectively, see Fig. 1). The median levels of the verbal IQ were 74 (Q_1 47; Q_3 99, range: 6–128) before surgery and 70 (Q_1 42; Q_3 95, range: 3–146) at follow-up (see Fig. 2). The median performance IQ was 70 (Q_1 45; Q_3 90, range: 6–126) with the same median of 70 at the two-year follow-up (Q_1 35; Q_3 93, range: 3–143) (see Fig. 3). For comparative reasons, the mean (SD) values for FSIQ, VIQ, and PIQ before surgery were 70 (29.87), 72 (31.38), and 68 (29.66), and the mean (SD) values two years after surgery were 67 (32.17), 68 (32.79), and 67 (32.61).

Table 1
Number, side of operation, gender, age at operation, and duration of epilepsy for the 94 children and adolescents related to the type of operation.

Type of operation	Number	Gender	Age at operation	Duration of epilepsy
	Total n (right:left hemisphere)	n female:male	Md (range, years:months)	Md (range, years:months)
Resections				
Temporal lobe	31 (16:15)	20:11	11:0 (3:8 to 18:7)	6:0 (0:2 to 16:5)
Frontal lobe	20 (8:12)	13:7	11:5 (3:10 to 16:1)	6:3 (1 to 14:11)
Parietal lobe	7 (4:3)	6:1	10:8 (9:6 to 18:4)	5:7 (2:7 to 10:5)
Occipital lobe	3 (2:1)	1:2	13:5 (12:10 to 16:7)	9:1 (0:4 to 13)
Multilobe	12 (8:4)	3:9	9:2 (2:9 to 17:6)	4:11 (2:2 to 10:10)
Hemispherectomy	10 (5:5)	1:9	5:5 (0:11 to 18:4)	5:0 (0:6 to 13)
Total	83 (43:40)	44:39	10:8 (0:11 to 18:7)	5:6 (0:2 to 16:5)
Nonresective surgery				
Callosotomy	7	2:5	9:10 (4:6 to 13:7)	5:6 (3 to 8:6)
Disconnection of hamartoma	2	0:2	11:9 (8:2 to 15:9)	12:0 (8:2 to 15:9)
Multiple subpial transection	2 (0:2)	2:0	15:6 (15:5 to 15:8)	11:10 (11:3 to 12:5)
Total	11 (0:2)	4:7	11:11 (4:6 to 15:9)	8 (3 to 15:9)
Total	94 (43:42; 9)	48:46	10:8 (0:11 to 18:7)	5:9 (0:2 to 16:5)

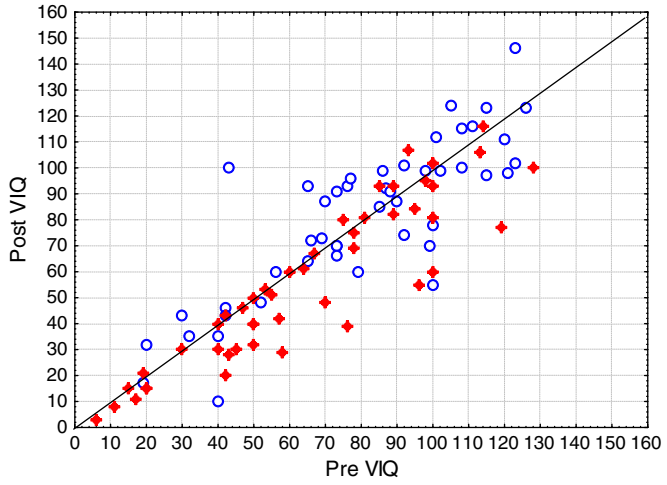

Fig. 2. The pre- versus postoperative verbal IQ (VIQ) in 47 seizure-free (circles) and 47 nonseizure-free (crosses) children and adolescents. The median (and quartile) change in VIQ for the seizure-free group was 1 (−7, 9), whereas it was −4 (−15, 0) for the nonseizure-free group.

4.1. Postoperative IQ level in relation to preoperative IQ

Before surgery, 49 (52%) of the 94 children and adolescents in the study group had an average full-scale IQ (>69), 17 (18%) had mild intellectual disabilities, and 28 (30%) had moderate-to-severe intellectual disabilities. The pre- and postoperative IQ scores in relation to preoperative IQ level are shown in Table 3.

Children with moderate-to-severe intellectual disabilities (n = 28): ten (36%) had a higher or unchanged postoperative full-scale IQ. The results for verbal IQ and performance IQ were 13/28 (46%) and 12/28 (43%) children, respectively. The median change in full-scale IQ was −3 IQ points (Q_1 −6; Q_3 0) (Figs. 1–3).

Children with mild intellectual disabilities (n = 17): the proportion of the children with a higher or unchanged postoperative full-scale IQ or verbal IQ score was nine of 17 (53%), while the figure for performance IQ was 12 of 17 (71%). The median change in full-scale IQ was 0 IQ points (Q_1 −14; Q_3 5) (Figs. 1–3).

Children with an average IQ (n = 49): the proportion of the children with a higher or unchanged postoperative full-scale IQ was 24/49 (49%); the corresponding proportions for verbal IQ and performance IQ were 21/49 (43%) and 27/49 (55%), respectively. The median change in full-scale IQ was −1 IQ point (Q_1 −11; Q_3 6) (Figs. 1–3).

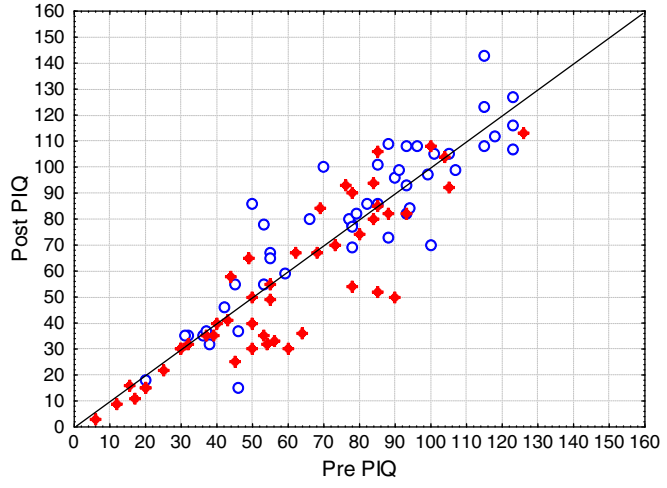

Fig. 3. The pre- versus postoperative performance IQ (PIQ) in 47 seizure-free (circles) and 47 nonseizure-free (crosses) children and adolescents. The median (Q_1, Q_3) change in PIQ for the seizure-free group was 2 (−6, 10), whereas it was −2 (−10, 5) for the nonseizure-free group.

Table 2
Number of children with a higher or unchanged full-scale IQ (FSIQ) related to seizure outcome two years after surgery and preoperative IQ level.

Seizure outcome two years after surgery	FSIQ > 69, higher or unchanged IQ	FSIQ = 50–69, higher or unchanged IQ	FSIQ < 50, higher or unchanged	Total higher or unchanged IQ
Seizure-free	18/30 (60%)	6/7 (86%)	4/10 (40%)	28/47 (60%)
Not seizure-free	6/19 (32%)	3/10 (30%)	6/18 (33%)	15/47 (32%)
Total	24/49 (49%)	9/17 (53%)	10/28 (36%)	43/94 (46%)

4.2. Postoperative IQ level in relation to seizure outcome

At the two-year follow-up, the majority, 65, of the children (69%) had a reduction in seizure frequency of at least 75%: 47 of the 94 children and adolescents (50%) were seizure-free, and 18 (19%) had a reduction in seizure frequency of more than 75%. Sixteen were off medication at follow-up, whereas 31 were still on medication at follow-up. Among the remaining nonseizure-free children, 14 (15%) had a 50–75% reduction, and 12 (13%) had a less-than-50% reduction. Three children had an increase in seizure frequency.

Figs. 1–3 show the changes in full-scale IQ, verbal IQ, and performance IQ, respectively, in the 47 seizure-free and the 47 nonseizure-free children and adolescents.

A significant difference in the median levels of change in full-scale IQ was found between the seizure-free and nonseizure-free children two years after surgery, where the median levels of change were 2 (Q_1 −6; Q_3 6) and −5 IQ points (Q_1 −15; Q_3 0) respectively ($p = 0.009$). Twenty-eight (60%) of the 47 seizure-free children and 15 (32%) of the 47 nonseizure-free children had a higher or unchanged full-scale IQ at follow-up (Fig. 1). This difference of 28% (60% versus 32%) was significant (the 95% CI for the difference was 8% to 45%, $p < 0.01$).

The median level of change in verbal IQ was an increase of one IQ point (Q_1 −7; Q_3 9) in the seizure-free group and a decrease of four IQ points (Q_1 −15; Q_3 0) in the nonseizure-free group ($p = 0.016$). Twenty-six (55%) of the 47 seizure-free children and 17 (36%) of the 47 nonseizure-free children had a higher or unchanged verbal IQ at follow-up (Fig. 2). The 95% CI for this difference of 19% (55% versus 36%) was −0.9% to 37%.

There was also a significant difference in the median levels of change in performance IQ between the seizure-free and nonseizure-free children, where the median level of change was an increase of two IQ points (Q_1 −6; Q_3 10) and a decrease of two IQ points (Q_1 −10; Q_3 5), respectively ($p = 0.05$). Thirty (64%) of the seizure-free children and 22 (47%) of the nonseizure-free children had a higher or unchanged performance IQ (Fig. 3). The 95% CI for this difference of 17% (64% versus 47%) was −3% to 35%. Out of the 16 seizure-free children who were off medication at the follow-up, 11 (69%) had a higher or unchanged performance IQ. The corresponding figure was 19 of 31 (61%) for those who were seizure-free but still on medication.

The pre- and postoperative IQ scores in relation to the preoperative IQ level in the seizure-free and nonseizure-free groups are shown in Table 3.

Children with moderate-to-severe intellectual disabilities (n = 28): ten (36%) were seizure-free at the two-year follow-up. A higher or unchanged full-scale IQ was found in four of the ten seizure-free children and in six of the 18 nonseizure-free children (Fig. 1).

Children with mild intellectual disabilities (n = 17): seven (41%) were seizure-free at the two-year follow-up. Six (86%) of them had a higher or unchanged full-scale IQ, compared with three of the ten nonseizure-free children (Fig. 1).

Table 3
Pre- and postoperative full-scale IQ (FSIQ), verbal IQ (VIQ), and performance IQ (PIQ) for the seizure-free and nonseizure-free children and adolescents related to preoperative IQ level.

Preoperative IQ	Pre-FSIQ	Post-FSIQ	Post-FSIQ	Pre-VIQ	Post-VIQ	Post-VIQ	Pre-PIQ	Post-PIQ	Post-PIQ
		Seizure-free	Not seizure-free		Seizure-free	Not seizure-free		Seizure-free	Not seizure-free
	Md (range)	Md (range)	Md (range)	Md (range)	Md (range)	Md (range)	Md (range)	Md (range)	(Md range)
IQ > 69	93 (70–127) n = 49	93.5 (62–148) n = 30	85 (47–113) n = 19	93 (40–146) n = 49	97.5 (55–145) n = 30	84 (40–116) n = 19	92 (50–143) n = 49	98 (69–143) n = 30	82 (50–113) n = 19
IQ 50–69	60 (50–69) n = 17	65 (55–100) n = 7	42.5 (34–80) n = 10	65 (30–79) n = 17	72 (43–93) n = 7	49 (29–80) n = 10	55 (43–70) n = 17	65 (55–100) n = 7	40.5 (30–84) n = 10
IQ < 50	40 (6–48) n = 28	36 (15–93) n = 10	30 (3–58) n = 18	40 (6–64) n = 28	39 (10–100) n = 10	29 (3–61) n = 18	36.5 (6–55) n = 28	35 (15–78) n = 10	30 (3–65) n = 18

Children with an average IQ (n = 49): thirty (61%) were seizure-free at the two-year follow-up. Eighteen of them (60%) had a higher or unchanged full-scale IQ postoperatively, compared with six (32%) of the 19 nonseizure-free children (Fig. 1).

4.3. Cognitive outcome in relation to type of surgery

The pre- and postoperative IQ scores in relation to the type of surgery and seizure outcome are shown in Table 4.

Temporal lobe resection was performed in 31 children, five of whom had a moderate-to-severe intellectual disability and three a mild intellectual disability. Fourteen children (45%) had a higher or unchanged full-scale IQ and verbal IQ, while for performance IQ, the corresponding proportion was 13/31 (42%). The median change in verbal IQ was −3 IQ points in the children operated on the left temporal lobe and −1.5 IQ points in the children operated on the right temporal lobe. There was a higher or unchanged verbal IQ in seven (47%) of the 15 children operated on the left temporal lobe and seven (44%) of the 16 operated on the right temporal lobe.

Frontal lobe resection was performed in 20 individuals; seven of them had a moderate-to-severe intellectual disability and three a mild intellectual disability. Nine (45%) had a higher or unchanged full-scale IQ and verbal IQ, while the corresponding proportion for performance IQ was 12/20 (60%).

Parietal lobe resection was performed in seven children. One child had a moderate-to-severe intellectual disability and two a mild intellectual disability. Four had a higher or unchanged full-scale IQ and verbal IQ, and the corresponding number for performance IQ was three.

Occipital lobe resection was performed in three children, all with average intelligence. Two children had a higher full-scale IQ and three a higher performance IQ. None had a higher verbal IQ two years after surgery.

Multilobe resection was performed in 12 children; three of them had a moderate-to-severe intellectual disability and two a mild intellectual disability. Five had a higher or unchanged full-scale IQ and verbal IQ, and the corresponding number for performance IQ was seven.

Hemispherectomy was performed in ten children; five had a moderate-to-severe intellectual disability and four a mild intellectual disability. Half of the children had a higher or unchanged full-scale IQ and verbal IQ, while a higher performance IQ was found in one child.

For the results in the children undergoing nonresective surgery, see Table 4.

5. Discussion

This study describes a consecutive series of all the children and adolescents undergoing surgery at one center and the individual changes in IQ scores two years after epilepsy surgery in relation to the preoperative IQ level. Special attention was focused on children with

Table 4
Pre- and postoperative full-scale IQ (FSIQ), verbal IQ (VIQ), and performance IQ (PIQ) for the seizure-free and nonseizure-free children and adolescents related to the type of operation.

	Pre-FSIQ	Post-FSIQ	Post-FSIQ	Pre-VIQ	Post-VIQ	Post-VIQ	Pre-PIQ	Post-PIQ	Post-PIQ
		Seizure-free	Not seizure-free		Seizure-free	Not seizure-free		Seizure-free	Not seizure-free
	Md (range)	Md (range)	Md (range)	Md (range)	Md (range)	Md (range)	Md (range)	Md (range)	Md (range)
Type of resection									
Temporal lobe	88 (25–127) n = 31	93 (21–148) n = 21	80 (30–105) n = 10	92 (19–128) n = 31	99 (17–146) n = 21	80.5 (20–100) n = 10	88 (20–126) n = 31	97 (18–143) n = 21	83 (30–113) n = 10
Frontal lobe	66.5 (14–117) n = 20	91 (73–119) n = 4	45.5 (11–113) n = 16	74.5 (11–119) n = 20	89 (70–115) n = 4	47 (8–116) n = 16	61 (12–115) n = 20	95 (80–123) n = 4	47 (9–108) n = 16
Parietal lobe	78 (45–90) n = 7	76.5 (47–100) n = 4	76 (47–77) n = 3	77 (42–96) n = 7	82.5 (43–96) n = 4	75 (55–84) n = 3	80 (38–90) n = 7	75.5 (32–100) n = 4	74 (52–80) n = 3
Occipital lobe	103 (70–105) n = 3	109.5 (109–110) n = 2	50 (–) n = 1	101 (50–120) n = 3	111.5 (111–112) n = 2	40 (–) n = 1	90 (88–105) n = 3	107 (105–109) n = 2	50 (–) n = 1
Multilobe	71.5 (20–100) n = 12	72 (40–92) n = 6	59.5 (15–104) n = 6	71 (20–100) n = 12	71.5 (43–87) n = 6	61.5 (15–102) n = 6	75.5 (20–93) n = 12	80 (46–101) n = 6	53 (15–106) n = 6
Hemispherectomy	52.5 (29–100) n = 10	60 (15–93) n = 9	45 (–) n = 1	51.5 (20–100) n = 10	55 (10–100) n = 9	60 (–) n = 1	49.5 (31–100) n = 9	55 (15–78) n = 9	30 (–) n = 1
Palliative operation									
Callosotomy	40 (6–80) n = 7	42 (–) n = 1	39 (3–60) n = 6	50 (6–100) n = 7	60 (–) n = 1	44 (3–60) n = 6	40 (6–55) n = 7	37 (–) n = 1	40.5 (3–55) n = 6
Disconnection of hamartoma	35 (22–48) n = 2	– n = 0	34 (22–46) n = 2	36 (19–53) n = 2	– n = 0	37 (21–53) n = 2	32 (25–39) n = 2	– n = 0	28.5 (22–35) n = 2
Multiple subpial transection	55 (48–62) n = 2	– n = 0	49.5 (33–66) n = 2	58.5 (50–67) n = 2	– n = 0	49.5 (32–67) n = 2	57.5 (53–62) n = 2	– n = 0	51 (35–67) n = 2
Total	70 (6–127) n = 94	84 (15–148) n = 47	47 (3–113) n = 47	74 (6–128) n = 94	87 (10–146) n = 47	51 (3–113) n = 47	70 (6–126) n = 94	82 (15–143) n = 47	50 (3–113) n = 47

moderate-to-severe or mild intellectual disabilities. The prevalence of intellectual disability was 48%, which is consistent with epidemiological studies of medically intractable childhood epilepsy [20–22].

Half of the 94 children and adolescents were seizure-free two years after surgery, 61% of those with a preoperative average IQ and 38% of those with intellectual disabilities. Corresponding proportions have been reported in other studies [9,23]. In spite of the fact that the preoperative IQ has been shown to be a predictor of seizure outcome two years after surgery [24] and a lower proportion of the children with intellectual disabilities became seizure-free, this group had a higher or unchanged IQ two years after surgery to the same extent as the children with an average preoperative IQ (42% and 49%, respectively). This was true for full-scale IQ and verbal IQ but was most obvious for performance IQ in the children with a mild intellectual disability. Other studies have reported corresponding results two years after surgery [11,25,26]. A higher performance IQ was reported in children after temporal lobe surgery [11,27,28]. These results were not related to the preoperative cognitive level, and most studies evaluating intelligence in children report no long-term postsurgical deterioration in intelligence scores [15,29–31].

It may be argued that the gain in performance IQ in some children in this study could be an effect of practice and not of an improvement in cognitive capacity. When serial cognitive assessments of children are performed, the test–retest reliability of the test instruments that are used, the effects of practice, and the child's maturation must be considered. Assessments of intelligence recognize maturation and practice effects by using age-corrected normative scores. When the period between the first test and reassessment extends over two years, as in this study, the child is expected to tackle a considerably larger number of tasks to reach the same IQ level. For this reason, there should be no practice effect in this study. The positive change in performance IQ may be due to improvements in cognitive capacity, together with gains in attention and speed, especially in the seizure-free children. It could not be explained by the withdrawal of anti-epileptic drugs in these children.

No appropriate normative data or test batteries have been constructed for children with intellectual disabilities. The clinical practice for this group is to use intelligence tests or developmental scales appropriate to their functional level instead of their chronological age and to calculate an age-related IQ equivalent. When evaluating the present results, it is important to take account of the fact that the child had to develop at a pace that was at least equivalent to that expected in a healthy child during a 24-month period, in order to remain at the same IQ level or to obtain higher IQ scores. For children with intellectual disabilities and slow development of cognitive capabilities, a loss in IQ scores is expected over the years, but this does not represent a loss of cognitive ability [8,32]. An extrapolation of the IQ trajectory preceding surgery would be the expected “baseline” with which the postoperative IQ should ideally be compared. A maintained and a slightly reduced IQ may thus reflect a positive development. The results in this study should not be attributed to the choice of method, as the same test instruments were used for the assessments of intelligence or developmental level before surgery and at follow-up for all children and, moreover, each child was its own control, making the comparison of changes more reliable. One limitation of the study was that the number of children in each subgroup was small, making comparisons between groups difficult.

The children with a mild intellectual disability who became seizure-free appeared to benefit the most with respect to cognitive outcome. Their seizure situation is often disastrous before surgery, and even a reduction in seizure frequency may have a positive effect on their cognitive development. The findings thus suggest that children with intellectual disabilities may benefit at least as much as children of average intelligence.

The early onset of epilepsy and age at surgery are other factors that have been shown to influence development [3,33], factors that were not analyzed in this study.

The present results represent the cognitive outcome two years after surgery, and it is possible that the cognitive outcome may improve in a longer perspective, as found by Skirrow et al. [11], but not supported by our previously reported findings ten years after surgery [34].

6. Conclusion

Intelligence quotient remained stable two years after epilepsy surgery in 94 children and adolescents. A seizure-free outcome was the most important factor for the prognosis of cognitive development, regardless of the intellectual level of the child before surgery. However, children with persisting yet significantly reduced seizure frequency could also benefit from surgery, especially the subgroup with a preoperative mild intellectual disability. Children with intellectual disabilities appeared not to lose cognitive function any more than those with average IQ. For this reason, children with intellectual disabilities and medically intractable epilepsy should be referred to a tertiary center and considered for epilepsy surgery, since they stand a good chance to achieve not only seizure freedom but also a slight cognitive improvement.

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References

[1] Dodrill CB. Neuropsychological effects of seizures. Epilepsy Behav 2004;5:21–4.
[2] Smith ML, Elliot IM, Lach L. Cognitive skills in children with intractable epilepsy: comparison of surgical and nonsurgical candidates. Epilepsia 2002;43:631–7.
[3] Vasconcellos E, Wyllie E, Sullivan S, Stanford L, Bulacio J, Kotagal P, et al. Mental retardation in pediatric candidates for epilepsy surgery: the role of early seizure onset. Epilepsia 2001;42:268–74.
[4] Sillanpää M. Long-term outcome of epilepsy. Epileptic Disord 2000;2:79–88.
[5] Mathern GW, Giza CC, Yudovin S, Vinters HV, Peacock WJ, Shewmon DA, et al. Postoperative seizure control and antiepileptic drug use in pediatric epilepsy surgery patients: the UCLA experience, 1986–1997. Epilepsia 1999;40:1740–9.
[6] Freitag H, Tuxhorn I. Cognitive function in preschool children after epilepsy surgery: rationale for early intervention. Epilepsia 2005;46:561–7.
[7] Shields WD. Surgical treatment of refractory epilepsy. Curr Treat Options Neurol 2004;6:349–56.
[8] Levisohn PM. Epilepsy surgery in children with developmental disabilities. Semin Pediatr Neurol 2000;7:194–203.
[9] Bjørnæs H, Stabell KE, Heminghyt E, Roste GK, Bakke SJ. Resective surgery for intractable focal epilepsy in patients with low IQ: predictors for seizure control and outcome with respect to seizures and neuropsychological and psychosocial functioning. Epilepsia 2004;45:131–9.
[10] McLellan IA, Davies S, Heyman I, Harding B, Harkness W, Taylor D, et al. Psychopathology in children with epilepsy before and after temporal lobe resection. Dev Med Child Neurol 2005;47:666–72.
[11] Skirrow C, Cross JH, Cornmack F, Harkness W, Vargha-Khadem F, Baldeweg T. Long-term intellectual outcome after temporal lobe surgery in childhood. Neurology 2011;76:1330–7.
[12] van Empelen R, Jennekens-Schinkel A, Buskens E, Helders PJM, van Nieuwenhuizen O. Functional consequences of hemispherectomy. Brain 2004;127:2071–9.
[13] Gonzalez-Martinez JA, Gupta A, Kotagal P, Lachhwani D, Wyllie E, Lüders HO, et al. Hemispherectomy for catastrophic epilepsy in infants. Epilepsia 2005;46:1518–25.
[14] Villarejo-Ortega F, Garcia-Fernandez M, Fournier-DelCastillo C, Fabregate-Fuente M, Alvarez-Linera J, De Prada-Vicente I, et al. Seizure and developmental outcome after hemispherectomy in children and adolescents with intractable epilepsy. Childs Nerv Syst 2013;29:475–88.
[15] Smith ML, Elliot IM, Lach L. Cognitive, psychosocial, and family function one year after pediatric epilepsy surgery. Epilepsia 2004;45:650–60.
[16] Olsson I, Danielsson S, Hedström A, Nordborg C, Viggedal G, Uvebrant P, et al. Epilepsy surgery in children with accompanying impairments. Eur J Paediatr Neurol 2013. http://dx.doi.org/10.1016/j.ejpn.2013.06.004 [pii: S1090-3798(13)00104-9].
[17] Swedish version of ICD 10; 1997.
[18] Newcombe RG, Altman DG. Proportions and their differences. In: Altman DG, Machin D, Bryant TN, Gardner MJ, editors. Statistics with confidence. 2nd ed. Bristol: BMJ books; 2000. p. 45–57.
[19] Altman DG. Practical statistics for medical research. London: Chapman & Hall; 1991.

[20] Sillanpää M. Epilepsy in children: prevalence, disability, and handicap. Epilepsia 1992;3:444–9.
[21] Sidenvall R, Forsgren L, Heijbel J. Prevalence and characteristics of epilepsy in children in northern Sweden. Seizure 1996;52:139–46.
[22] Waaler PE, Blom BH, Skeidsvoll H, Mykletun A. Prevalence, classification and severity of epilepsy in children in western Norway. Epilepsia 2000;41:802–10.
[23] Wyllie E, Comair YG, Kotagal P, Bulacio J, Bingaman W, Ruggieri P. Seizure outcome after epilepsy surgery in children and adolescents. Ann Neurol 1998;44:740–8.
[24] Malmgren K, Olsson I, Engman E, Flink R, Rydenhag B. Seizure outcome after resective epilepsy surgery in patients with low IQ. Brain 2008;131:535–42.
[25] Gleissner U, Clusmann H, Sassen R, Elger CE, Helmstaedter C. Postsurgical outcome in pediatric patients with epilepsy: a comparison of patients with intellectual disabilities, subaverage intelligence, and average-range intelligence. Epilepsia 2006;47:406–14.
[26] Granström ML, Kantola-Sorsa E, Gaily E, Paetau R, Liukkonen E, Boman PA, et al. Two-year follow-up of intelligence after pediatric epilepsy surgery. Pediatr Neurol 2005;33:173–8.
[27] Miranda C, Smith ML. Predictors of intelligence after temporal lobectomy in children with epilepsy. Epilepsy Behav 2001;2:13–9.
[28] Westerveld M, Sass KJ, Chelune GJ, Hermann BP, Barr WB, Loring DW, et al. Temporal lobectomy in children: cognitive outcome. J Neurosurg 2000;92:24–30.
[29] Bizzi JW, Bruce DA, North R, Elterman R, Linder S, Porter-Levy S. Surgical treatment of focal epilepsy in children: results in 37 patients. Pediatr Neurosurg 1997;26:83–92.
[30] Kirkpatrick PJ, Honavar M, Janota I, Polkey CE. Control of temporal lobe epilepsy following en bloc resection of low grade tumors. J Neurosurg 1993;78:19–25.
[31] Pulsifer MB, Brandt J, Salorio CF, Vining EP, Carson BS, Freeman JM. The cognitive outcome of hemispherectomy in 71 children. Epilepsia 2004;45:243–54.
[32] Besag FM. Childhood epilepsy in relation to mental handicap and behavioural disorders. J Child Psychol Psychiatry 2002;43:103–31.
[33] Cormack F, Cross JH, Isaacs E, Harkness W, Wright I, Vargha-Khadem F, et al. The development of intellectual abilities in pediatric temporal lobe epilepsy. Epilepsia 2007;48:201–4.
[34] Viggedal G, Kristjansdottir R, Olsson I, Rydenhag B, Uvebrant P. Cognitive development from two to ten years after pediatric epilepsy surgery. Epilepsy Behav 2012;25:2–8.