Effectiveness of Neuropediatric Inpatient Rehabilitation

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Abstract

Aim Inpatient rehabilitation plays an important role in treating neurological diseases in children and adolescents. However, there is a lack of current research concerning this matter. This retrospective study aims to analyze the effectiveness of neuropediatric inpatient rehabilitation, to identify influencing factors, and to examine the importance of inpatient rehabilitation programs.

Methods We reviewed medical records of patients, diagnosed with cerebral palsy, traumatic brain injury (TBI), or stroke who had an inpatient rehabilitation at the Department of Neuropediatrics of St. Mauritius Therapieklinik in Meerbusch from 2012 to 2019. The patients received several units of different therapies such as motor and cognitive rehabilitation or speech therapy per day, depending on their individual needs and aims. Rehabilitation outcome was assessed by comparing Gross Motor Function Measure-88 and Pediatric Evaluation of Disability Inventory admission and discharge scores. Influences of sex, age, length of stay (LOS), and admission score were analyzed.

Results A total of 738 patients with a mean age of 9.2 (± 5.1) years and a mean LOS of 53.8 (± 33.7) days were included; 38.5% were female. Patients, regardless of their diagnosis, sex, or age, demonstrated highly significant and meaningful improvements of self-care, mobility, and social function during inpatient rehabilitation. Especially, the group of patients with TBI and stroke could approximate their skills substantially to the ones of healthy peers. A longer LOS correlated significantly with greater improvement of skills.

Interpretation This is a current study, supporting the effectiveness of neuropediatric inpatient rehabilitation and affirming its value in treating neurological diseases in children and adolescents.

Keywords
- rehabilitation
- neuropediatric
- outcome
- cerebral palsy
- traumatic brain injury
- stroke

Background

According to the World Health Organization, rehabilitation means helping people with (threatening) disabilities to enable or maintain interactions with their environment. It aims to prevent or slow down the loss of function, restore and improve functions, compensate the loss of function, or maintain the current state of function.[1]

The rehabilitation of children and adolescents accounts for an important part of all rehabilitation therapies. In 2020, the legal health insurance and the public pension insurance

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companies counted around 32,360 inpatient rehabilitation stays of children and adolescents in Germany, 1,383 of which were due to neurological diseases.[2,3]

Several studies have shown that children and adolescents with neurological diseases can improve various skills during inpatient rehabilitation.[4–7] Nevertheless, there is a lack of thorough and especially current studies of effectiveness and influencing factors on the outcome of neuropediatric inpatient rehabilitation. To analyze these questions, we conducted a retrospective study,[8] the results of which are presented in this article.

Methods

We reviewed patients' records from July 2012 to March 2019 of the Departments of Neuropediatric of St. Mauritius Therapieklinik in Meerbusch. Patients diagnosed with cerebral palsy (CP), traumatic brain injury (TBI), or stroke were included in our study, as they represented the largest groups of patients and allowed a comparison of patients with different brain injuries. Further inclusion criteria were a length of stay (LOS) of at least 21 days and a maximum age of 18 years at the beginning of rehabilitation. Information was collected regarding sex, age, severity or type of impairment, LOS, and a learning or cognitive disability. For patients with CP, Gross Motor Function Classification System (GMFCS) was used to determine the severity,[9] and in patients with TBI, initial Glasgow coma scale scores were used. Furthermore, the patients with CP were divided into two subgroups: "acute" and "not acute." A rehabilitation was considered "acute" when there had been an operation performed in the 6-month period before the inpatient rehabilitation stay. Otherwise, the rehabilitation was identified as "not acute." As this was a retrospective study, information on learning/cognitive disability, severity, type of impairment, or the fact, whether there had been an operation prior to the rehabilitation could only be collected, if mentioned in the medical records.

In the Department of Neuropediatrics of St. Mauritius Therapieklinik in Meerbusch, a multimodal, evidence-based concept is applied in inpatient rehabilitation.[10] The patients are offered strength training, swimming and physiotherapy, *constraint-induced movement therapy*, or electrotherapy. For gait training, the Lokomat® and Woodway treadmills with weight unloading are used among others. Speech therapy, music and occupational therapy, cognitive rehabilitation, and educational assistance are also offered. Furthermore, psychological and social support is provided to the patients and their parents or caregivers. The patients receive several units of individual and group therapies per day. A typical day of a 9-year-old adolescent with unilateral-spastic CP, GMFCS III, during inpatient rehabilitation could look like this: 8 a.m. breakfast and ward round; 9 to 10 a.m. school lesson (60 or 120 minutes); 10 to 11 a.m. strength training; 11 to 11.30 a.m. motor therapy, individual coaching (gait, lower limb); 11.30 a.m. to 12/12.30 p.m. music therapy (group); 12 p.m. lunch break; 1.30 to 2.30 p.m. "Motozirkus" (mobility, balance, coordination, endurance); 3 to 4 p.m. motor therapy (hand/upper limb, depending on individual aims); and 4 to 5 p.m. swimming therapy (group).

The skills of all the children and adolescents are evaluated at admission and discharge by standardized measuring instruments, allowing an individual control of success of the patients.

As measuring instruments, the Gross Motor Function Measure-88 (GMFM) and the Pediatric Evaluation of Disability Inventory (PEDI) were used.

The GMFM is a valid and reliable instrument for the evaluation of gross motor function in children and adolescents.[11–14] It consists of 88 items, which are assessed by therapists and summed up to a *total score* of maximum 100 points.[14] Therapists saw an increase of seven points during rehabilitation as a meaningful change of skills, according to the authors.[13,14]

The PEDI is a comprehensive clinical assessment that samples functional capabilities and performance in children.[15] It also showed good reliability and validity.[15–17] We focused on the functional skills scales in the domains self-care, mobility, and social function, which were rated by the parents or the patients themselves by a questionnaire. The PEDI is standardized for children from 6 months to 7.5 years (*normative standard scores*), but it can be used for older patients as well.[15] The *normative standard scores* indicate the level of functioning regardless of age, and allow a comparison of the skills of our patients with the ones of healthy peers. Furthermore, there can be calculated *scaled scores*, which are not standardized and can be generated and used for all ages. They represent the functional skills of the patients on a scale from 0 to 100, and are based on the Rasch analysis. Higher scores reflect better functioning.[15] An improvement of 11 points on these scales was observed to be clinically meaningful.[7]

GMFM's *total scores* as well as *scaled scores* and *normative standard scores* of the PEDI were tested for statistically significant differences between admission and discharge. Our data were not normally distributed, so the Wilcoxon test was used for linked group comparisons and the Mann–Whitney *U*-test was used for unlinked group comparisons. As effect size for the Wilcoxon test, we calculated *r*, formula: $r = \left(\left|\frac{z}{\sqrt{n}}\right|\right)$.[18] Following Cohen, effect sizes were ranked as: small effect ($r = 0.1$), medium effect ($r = 0.3$), and large effect ($r = 0.5$).[19] Correlations were calculated using Spearman's correlation. A result of $p \leq 0.05$ was considered significant. We used Bonferroni's correction for multiple testing.

The study was approved by the ethics committee of the Medical Association of Westphalia-Lippe and the University of Münster (2019-208-f-S, July 22, 2019).

Results

A total of 738 children and adolescents with a mean age of 9.2 (±5.1) years and a mean rehabilitation LOS of 53.8 days (±33.7) were included in the study; 38.5% (284) of the patients were female. We separated our patients into four groups: CP acute, CP not acute, TBI, and stroke. There was missing information on acute/not acute for 19 patients with CP. ►**Table 1** gives a more detailed overview of our patient's characteristics.

Table 1 Characteristics of our study population

	CP acute	CP not acute	TBI	Stroke
Total number	264	220	143	92
Female	90	94	63	30
Age	9.52 (4.29)	8.22 (5.23)	10.17 (5.5)	9.21 (5.99)
LOS	53.49 (26.07)	47.22 (20.77)	59.15 (52.51)	62.43 (40.27)
Intelligence				
Learning/cognitive disability	87	89	7	7
No learning/cognitive disability	161	126	111	73
Missing	16	5	25	12
Severity/type of impairment	GMFCS I: 18 II: 35 III: 54 IV: 75 V: 60 Missing: 22	GMFCS I: 26 II: 29 III: 46 IV: 48 V: 35 Missing: 36	Initial GCS 13–15: 21 9–12: 18 $\leq$ 8: 68 Missing: 36	Type of stroke Hemorrhagic: 41 Ischemic: 39 Missing: 12

Abbreviations: CP, cerebral palsy; GCS, Glasgow coma scale; GMFCS, Gross Motor Function Classification System; LOS, length of stay; TBI, traumatic brain injury.
Notes: The absolute numbers are given. Age is indicated in years (±standard deviation [SD]), LOS is indicated in days (±SD).

First, admission and discharge GMFM *total scores* and PEDI *scaled scores* were tested for statistically significant differences. ►**Table 2** shows the median scores at admission and discharge as well as the difference between admission and discharge and the result of the statistical test. It can be seen that there were highly significant improvements of self-care, mobility, and social function. In addition, the calculated effect sizes show a large effect (i.e., $r \geq 0.5$) in almost all areas.

Next, we analyzed whether our patients reached a clinically meaningful change (cmc) of skills during rehabilitation in GMFM *total scores* and PEDI *scaled scores*. ►**Table 3** shows the patients who were able to achieve a cmc, the number of patients who had such a high level of skills at the start of rehabilitation that they were technically not able to achieve a cmc, and the patients who could not reach a cmc.

In the GMFM *total score*, more than 50% of the patients achieved a cmc during rehabilitation. In the PEDI *scaled scores*, a cmc was seen less frequently. Mostly, patients with TBI achieved a meaningful improvement. At the same time, patients with TBI or stroke often already had very high level of skills at the beginning of rehabilitation compared with patients with CP.

Furthermore, the PEDI *normative standard scores* were analyzed in the subgroup of patients with the age of 6 months to 7.5 years. ►**Fig. 1** shows the admission and discharge scores, separated into the diagnostic subgroups (CP acute/not acute, TBI, and stroke).

There was a highly significant improvement ($p < 0.001$) of skills in all scales from admission to discharge. In particular, children with TBI and stroke could approximate their level of skills to the ones of healthy peers.

In a second step, the influence of sex, age at the beginning of rehabilitation, LOS, and admission score on rehabilitation outcome was analyzed. The influence of sex was examined by comparing groups of male and female patients. The relationship of age, LOS, and admission score with rehabilitation outcome was examined using Spearman's correlation. ►**Table 4** gives an overview of all results.

No significant differences were found between male and female patients. Age at the beginning of rehabilitation also had no significant influence, except for a weak correlation in the mobility scale of the PEDI. However, a positive correlation was seen between the rehabilitation LOS and the improvement of all functional skills. Significant correlations between admission score and improvement were observed in the GMFM, where patients improved slightly more if they had lower abilities at admission. Regarding the self-care scale of the PEDI, an opposite relationship was found.

Discussion

First, it was observed that children and adolescents with CP, TBI, and stroke significantly improved their functional skills in self-care as well as their motor and social function during neuropediatric inpatient rehabilitation. Rehabilitation mostly had a large effect on the improvement of skills. Furthermore, especially patients with TBI and stroke often achieved a clinically meaningful improvement, more frequent than patients with CP. One explanation for these results could be the different timing of brain damage. The group of patients with TBI and stroke mainly came to rehabilitation shortly after the occurrence of the brain damage, so that the effects of rehabilitation and spontaneous regeneration probably overlap here. In patients with CP, on the other hand, the brain damage happens during pregnancy or in the neonatal period, so that the effect of spontaneous regeneration is absent in the context of rehabilitation. This aspect should be studied in more detail in

Table 2 Median admission and discharge scores and significance of the difference

	Admission	Discharge	Diff.	*Z*	Effect size (*r*)
CP not acute					
GMFM ($n = 214$)	35.5 (17.0–64.9)	51.0 (25.0–76.0)	15.5[a]	−12.538	0.61
PEDI ($n = 213$)					
Self-care	46.7 (35.1–61.8)	49.6 (37.8–66.8)	2.9[a]	−11.14	0.54
Mobility	41.4 (27.3–58.7)	46.1 (31.3–63.4)	4.7[a]	−10.466	0.51
Social function	52.6 (39.6–67.4)	54.3 (40.8–69.9)	1.7[a]	−8.24	0.40
CP acute					
GMFM ($n = 259$)	22.0 (8.0–38.0)	39.0 (17.6–66.0)	17.0[a]	−13.898	0.61
PEDI ($n = 253$)					
Self-care	48.2 (33.0–59.9)	51.0 (37.4–66.8)	2.8[a]	−11.891	0.53
Mobility	32.0 (15.2–43.3)	41.4 (24.4–54.8)	9.4[a]	−12.565	0.56
Social function	55.4 (41.1–65.7)	56.6 (41.8–67.4)	1.2[a]	−8.585	0.38
TBI					
GMFM ($n = 138$)	69.9 (38.4–95.3)	96.5 (87.0–100)	26.6[a]	−9.547	0.57
PEDI ($n = 134$)					
Self-care	72.2 (50.1–100)	100 (68.9–100)	27.8[a]	−8.148	0.50
Mobility	60.0 (40.1–79.8)	89.2 (63.9–100)	29.2[a]	−8.895	0.54
Social function	67.2 (53.4–89.1)	85.7 (62.9–100)	18.5[a]	−8.148	0.50
Stroke					
GMFM ($n = 88$)	70.0 (26.0–95.0)	92.5 (61.7–99.9)	22.5[a]	−7.309	0.55
PEDI ($n = 86$)					
Self-care	57.7 (44.2–79.6)	73.1 (53.4–100)	15.4[a]	−6.847	0.52
Mobility	56.5 (30.6–74.9)	72.5 (55.9–100)	16.0[a]	−6.736	0.51
Social function	61.1 (48.7–82.2)	75.4 (54.3–97.2)	14.3[a]	−6.351	0.48

Abbreviations: CP, cerebral palsy; GMFM, Gross Motor Function Measure-88; PEDI, Pediatric Evaluation of Disability Inventory; TBI, traumatic brain injury.

Notes: Indicated are the medians with interquartile range of the GMFM-total scores and the PEDI-scaled scores as well as the effect size (*r*) and the Z-scores of the Wilcoxon's test.

[a] $p < 0.001$ (Wilcoxon test). Using Bonferroni's correction, $p < 0.003$ is considered significant.

further studies as, unfortunately, we did not have sufficient data to analyze this question.

We analyzed whether our patients could reach a cmc of their scores during rehabilitation as we hoped to better understand the importance of the improvements made by our patients. It is difficult to derive the meaning of an improvement by just looking at the amount of change of a measuring instrument, not also the time, during which the improvement takes place. By the developers, an increase of seven points in the GMFM during 4 to 6 months was seen as clinically meaningful.[13,14] As the mean LOS of our patients was 53.8 (±33.7) days, we used this value in our study as well. Furthermore, there are no consistent methods to define a cmc. For the PEDI, for example, some authors calculated their own threshold values[20,21] and did not use the one suggested by the authors (which we used). It has to be considered, though, that this 11-point limit for the cmc was calculated in a very inhomogeneous group of patients, so on the one hand, it should be used with caution. On the other hand, an increase of 11 points during rehabilitation means a lot, compared with the amount, a child would probably improve without rehabilitation.[22] However, the individual goals and assessment of patients are relevant in practice as well. In our experience, even some minor progress can have great personal significance, which does not necessarily have to be reflected in scores. Therefore, other factors should also be included in future analyses, such as the degree to which a patient's specific goals are achieved. An approach to this is the goal attainment scaling, which can be used to measure the progress of a patient toward his or her individual goals.[23] It was developed for the field of mental health and geriatric medicine, but it can also be used to measure and better classify rehabilitation outcome in children.[24] As this was a retrospective study, we had no opportunity to use this or another comparable measuring instrument, but we would recommend all researchers to think about it in further studies. Another approach to better understand the therapy effectiveness was to analyze the

Table 3 Clinical meaningful change

		CP acute	CP not acute	TBI	Stroke
GMFM	[a]	70.7% (183)	56.1% (120)	61.6% (85)	52.3% (46)
	[b]	1.5% (4)	3.7% (8)	30.4% (42)	33.0% (29)
	[c]	27.8% (72)	40.2% (86)	7.9% (11)	14.8% (13)
PEDI					
Self-care	[a]	13.0% (33)	7.5% (16)	38.1% (51)	31.4% (27)
	[b]	2.8% (7)	3.8% (8)	35.8% (48)	20.9% (18)
	[c]	84.2% (213)	88.7% (189)	26.1% (35)	47.7% (41)
Mobility	[a]	32.0% (81)	11.7% (25)	56.7% (76)	45.3% (39)
	[b]	2.0% (5)	2.8% (6)	17.9% (24)	22.1% (19)
	[c]	66.0% (167)	85.4% (182)	25.4% (34)	32.6% (28)
Social function	[a]	4.3% (11)	5.2% (11)	27.6% (37)	25.6% (22)
	[b]	7.1% (18)	10.8% (23)	28.4% (38)	22.1% (19)
	[c]	88.6% (224)	84.0% (179)	44.1% (59)	52.3% (45)

Abbreviations: CP, cerebral palsy; GMFM, Gross Motor Function Measure-88; PEDI, Pediatric Evaluation of Disability Inventory; TBI, traumatic brain injury.
Notes: Percentage (and absolute numbers) of patients. (Minor deviations from 100% are due to rounding).
[a]That showed a clinically meaningful change (cmc) during rehabilitation.
[b]Whose skills levels at the beginning of rehabilitation were already so high that they were not able to reach a cmc.
[c]That showed no cmc during rehabilitation.

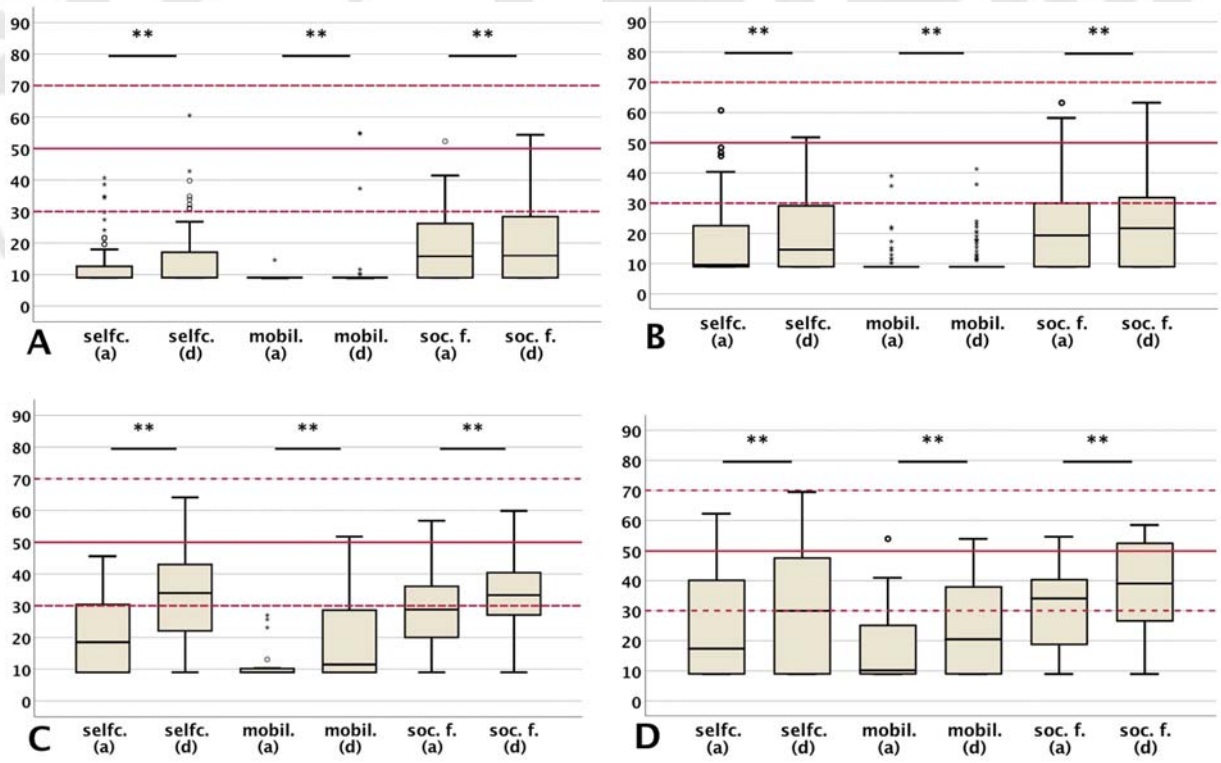

Fig. 1 Medians of PEDI normative standard scores (for children up to 7.5 years) at admission and discharge of patients with (**A**) CP acute ($n = 81$), (**B**) CP not acute ($n = 104$), (**C**) TBI ($n = 33$), and (**D**) stroke ($n = 33$). The medians of admission (a) and discharge (d) for self-care (selfc.), mobility (mobil.), and social function (soc. f.) are shown. The solid bold line represents the mean standard score of healthy peers (50 points), the dashed bold lines mark the range of ± 2 SD (30; 70). $^{**} = p < 0.001$ (Wilcoxon test). Using Bonferroni's correction, $p \leq 0.004$ is considered significant. CP, cerebral palsy; PEDI, Pediatric Evaluation of Disability Inventory; SD, standard deviation; TBI, traumatic brain injury.

Table 4 Relationship of influencing factors and improvement of GMFM *total scores* and PEDI *scaled scores*

	Sex	Age		LOS		Admission score	*p*
	p	*r*	*p*	*r*	*p*	*r*	
GMFM ($n = 718$)	0.638	−0.063	0.092	0.430	< 0.001	−0.197	< 0.001
PEDI ($n = 703$)							
Self-care	0.917	0.034	0.366	0.228	< 0.001	0.121	0.001
Mobility	0.396	0.147	< 0.001	0.275	< 0.001	−0.023	0.550
Social function	0.783	0.009	0.804	0.194	< 0.001	−0.008	0.827

Abbreviations: GMFM, Gross Motor Function Measure-88; LOS, length of stay; PEDI, Pediatric Evaluation of Disability Inventory.
Notes: Sex: Mann–Whitney *U*-test; age, LOS, admission score: Spearman's correlation. Using Bonferroni's correction, $p \leq 0.003$ is considered significant.

normative standard scores of the PEDI in the subgroup of patients under the age of 7.5 years. ►**Fig. 1** shows that especially patients with TBI or stroke could approximate their skills to the ones of healthy peers. These results could be explained by the reasons mentioned earlier.

In a second step, we analyzed potential influencing factors. In this study, no difference was found between male and female patients, which is consistent with the results of other studies.[25,26]

Our results further suggested that children and adolescents benefit from inpatient rehabilitation to a similar extent, regardless of their age at the beginning of rehabilitation.

On the contrary, a longer rehabilitation LOS was identified to have a positive influence on rehabilitation outcome, with the mean rehabilitation duration here being 7 to 8 weeks. This has also been described in previous studies[4,27] and confirms the importance of continuous skills training. The relationship between admission scores and rehabilitation outcome was partially opposite in the GMFM and PEDI. Some authors describe a negative correlation between the admission score and the rehabilitation outcome in children with TBI or other brain damage.[4,28] There were no studies found, that described an opposite correlation between GMFM and PEDI, as we found in our study. Further investigations should be performed on whether this is indeed related to the different skills, or rather to differences in the test procedures.

Limitations

The most important limitation of our study is the lack of a control group. We tried to compensate for it by using several methodical approaches, for example, by calculating effect sizes, using standardized scores of the PEDI or analyzing the meaning of a clinical change. In the future, different methods, such as the use of reference centiles as introduced by Duran et al[29] should be considered as well. This is a retrospective study, so it was not able to collect all the information of every patient. In addition, the results are also influenced by the selection and limitations of the measurement instruments used here, such as the absence of standardized, age-independent scores of the PEDI for children older than 7.5 years or the fact that the faster improvements of younger children could not be addressed in particular.

Conclusion

Our data suggest that neuropediatric inpatient rehabilitation leads to a highly significant improvement of self-care, and motor and social function, regardless of sex or age. Patients with TBI and stroke in particular showed huge benefits and often gained a cmc of function. A longer LOS was correlated with higher improvements in all functional skills.

In the future and based on the findings of this study, there should be conducted a prospective study with a defined examination period and a more homogeneous group of patients. Moreover, more attempts should be made to counteract the difficulty of not having a control group. Different methods or another study design should be used to even better understand the effectiveness of the inpatient rehabilitation program of the St. Mauritius Therapieklinik in Meerbusch.

Nevertheless, this is a current study of a large patient collective, supporting the importance and effectiveness of neuropediatric inpatient rehabilitation and affirming its value in treating different neurological diseases in children and adolescents.

Note

The study was conducted at the Department of Neuropediatrics, St. Mauritius Therapieklinik, Meerbusch.

Conflict of Interest

None declared.

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