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Correlation of Brain CT Findings and Developmental Outcome in Patients with Spastic Cerebral Palsy

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Brain computed tomography(CT) is a useful tool for evaluating the pathologic findings in the brains of children with neurologic abnormalities. Brain CT investigation and the Münchner Funtionelle Entwicklungs Diagnostik (MFED) developmental assessment was performed in 88 patients with spastic cerebral palsy. The incidence of abnormal brain CT findings in patients with spastic cerebral palsy was 69.3%. The group with pathologic CT findings had a greater possibility of having developmental delay than the group with normal CT findings($p<0.05$). However, there was no significant relationship between the specific MFED categories and the types of brain CT abnormalities. Pathological CT findings could offer important prognostic information indicating a higher risk concerning the grade of developmental delay.

Key Words: Spastic cerebral palsy, brain CT, developmental delay

Cerebral palsy is a disorder with very heterogenic clinical signs, etiology and prognosis. Many clinical investigations have shown the correlation between etiology and clinical types (Scherzer and Tscharnuter, 1986) and earlier neuroradiological and neuropathological investigations have shown a correlation between the clinical signs, etiology and pathologic findings in the brain(Wiklund and Uvebrant, 1991)

Brain computed tomography(CT) has made it possible non-invasively to evaluate and visualize pathoanatomic changes of the brain in patients with cerebral palsy. Several CT investigations have been performed in children with cerebral palsy(Jacoby *et al.* 1977; Brennan *et al.* 1978; Danziger and Price, 1980; Kotlarek *et al.* 1981). One of the frequent pathologic findings in cerebral palsy children on brain CT is atrophic changes, including ventricular dilatation, subarachnoid space widening and enlarged sulcal markings.

Few studies have been performed to evaluate the correlation between cranial CT findings and the developmental outcome of cerebral palsy (Picard *et al.* 1987; Uvebrant, 1988; Yokochi *et al.* 1989). An increasing frequency of pathologic brain CT findings in more severely motor handicapped spastic cerebral palsy children has been reported, but the grade of motor handicap was classified into only 3 groups in these studies (Taudorf and Melchior, 1984; Shouman-Claeys *et al.* 1989). There was also a report that cerebral palsied children with severe cognitive and intellectual sequelae tended to have abnormal CT findings (Kotlarek *et al.* 1981). For obtaining detailed information about development, more systematic developmental assessment is required. The Münchner Funtionelle Entwicklungs Diagnostik (MFED) test is one of the tools for assessing the development in children. There are two manuals;

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one is for infants and the other is for the 2~3 year olds. The manual for infants consists of eight categories, including creeping, sitting, walking, grasping, perception, speech, speech comprehension and socialization, while the manual for 2~3 year old toddlers consists of seven categories including gross motor, fine motor, perception, speech, speech comprehension, socialization and independence. The MFED test is a reliable and objective developmental test for children (Allhoff and Rennen-Allhoff, 1984). The aim of this study was to determine the correlation between the location and types of structural change of the brain and the developmental scores of MFED in children with spastic cerebral palsy.

MATERIALS AND METHODS

Eighty-eight spastic cerebral palsied children, 55 male and 33 female, who were admitted to the Department of Rehabilitation Medicine, Yonsei University College of Medicine between Jan. 1988 and Dec. 1992 were evaluated with brain CT and MFED developmental scores. The age of the patients ranged from 13 to 48 months (Table 1).

According to the topographic distribution, 63 children were spastic diplegia, 12 were spastic hemiplegia, 9 were spastic tetraplegia, 2 were spastic triplegia and 2 were spastic monoplegia.

Brain CT was performed and classified according to pathologic lesion in all patients. Bilateral atrophy was subdivided into cortical atrophy, central atrophy and generalized atrophy according to ventricular dilatation, subarachnoid space widening and interhemispheric fissure widening by the method of Pedersen et al. (1979). The infarction was defined as a well-demarcated low density area conforming to a vascular territory. A hemiatrophy was defined as a condition in which the volume of one hemisphere was less than the other. The presence of a malformation such as schizencephaly, corpus callosum anomaly was evaluated(Table 2).

The development was evaluated using the MFED test.

$$\text{MFED score (\%)} = \frac{\text{Mean developmental Age of MFED Categories(month)}}{\text{Chronological Age(month)}} \times 100$$

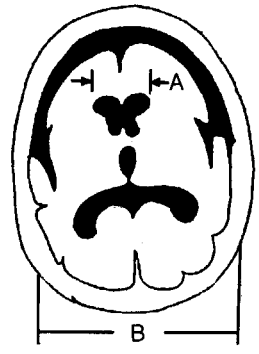
The correlation between MFED score and CT findings was analyzed statistically using Student

Table 1. Patient profile

Age(mo)	Male	Female	Total(%)
13~24	35	23	58 (66.0)
25~36	7	7	14 (15.8)
37~48	13	3	16 (18.2)
Total	55 (62.5)	33 (37.5)	88 (100.0)

Table 2. Classification of the brain CT lesion

1. Bilateral atrophy
   - A. Passive ventricular dilatation : a/b > 0.3
   - B. Subarachnoid space widening : subarachnoid space > 4 mm
   - C. Interhemispheric fissure widening
     age < 3 years : > 6.6 mm
     age ≥ 3 years : > 3.7 mm



   - Cortical atrophy : B and/or C
   - Central atrophy : A only
   - Generalized atrophy : A, B and C
2. Infarction
   Well-demarcated low attention area conforming to a vascular distribution.
3. Hemiatrophy
   The volume of one hemisphere less than the other.
4. Malformation
   Schizencephaly, corpus callosum anomaly, etc.

t-test and Kruscal-Wallis test.

RESULTS

The brain CT findings were normal in 27 cases (30.7%) and abnormal in 61 cases (69.3%). Abnormal brain CT findings were much more frequent in spastic hemiplegia compared to other types of cerebral palsy (Table 3).

Bilateral atrophy was the most frequent abnormal finding, followed by infarction and malformation. About half of the bilateral atrophy was generalized atrophy (19 out of 41 cases) which showed widened subarachnoid space and dilated lateral ventricles. Hemiatrophy was found only in spastic hemiplegia. Partial or total agenesis of corpus callosum was the most frequent finding of malformation (9 out of 16 cases), followed by schizencephaly (2 out of 16 cases)(Table 4).

The developmental score in relation to brain CT finding is shown in Table 5. The cerebral palsy children with abnormal brain CT findings had more severe developmental delay than those with normal brain CT findings in all categories of MFED ($p<0.05$).

Developmental scores and their mean rank by Kruskal-Wallis test according to pathologic brain CT findings are shown in Table 6. There was a tendency toward more severe developmental delay in groups with bilateral cortical atrophy, bilateral general atrophy, hemiatrophy, and infarction associated with bilateral cortical atrophy findings on CT scan than there was in groups with bilateral central atrophy,

Table 3. Brain CT findings in spastic cerebral palsy

Type	No. of Cases(%)		Total(%)
	Normal	Abnormal	
Diplegia	24 (38.1)	39 (61.9)	63 (100.0)
Hemiplegia	1 (8.3)	11 (91.7)	12 (100.0)
Tetraplegia	2 (22.2)	7 (77.8)	9 (100.0)
Triplegia	0 (0.0)	2 (100.0)	2 (100.0)
Monoplegia	0 (0.0)	2 (100.0)	2 (100.0)
Total	27 (30.7)	61 (69.3)	88 (100.0)

Table 5. MFED score according to CT findings

MFED Categories	CT Findings	
	Normal(n=27)	Abnormal(n=61)
Gross motor	62.4±25.4	47.6±29.9*
Fine motor	71.4±21.4	51.3±31.5*
Perception	79.9±24.2	56.5±32.7*
Speech	75.2±30.4	54.6±30.9*
Speech comprehension	83.6±27.5	56.9±32.5*
Social	79.1±20.3	58.3±31.6*
Independence	96.4±21.0	55.3±35.6*
Total	74.7±22.2	57.9±26.3*

Values are given as means±standard deviations,*: $p<0.05$

Table 4. Abnormal brain CT findings according to topographic distribution

CT Findings	Diplegia (n=39)	Hemiplegia (n=11)	Tetraplegia (n=7)	Triplegia (n=2)	Monoplegia (n=2)	Total (n=61)
Bilateral atrophy	24	8	6	1	2	41
Cortical atrophy	11	1	2		1	15
Central atrophy	1	2	2	1	1	7
General atrophy	12	5	2			19
Infarction	12	4	1	1	0	18
Malformation	11	2	3	0	0	16
ACC[1]	7	1	1	0	0	9
Schizencephaly	1	0	1	0	0	2
Others	3	1	1	0	0	5
Hemiatrophy	0	6	0	0	0	6

[1]: Partial or total agenesis of corpus callosum. Values are numbers of cases.

infarction, malformation and malformation associated with bilateral cortical atrophy findings.

The correlation between specific MFED categories and the types of brain CT pathologies were analyzed using a Friedman test. There was no significant correlation between the specific MFED categories and the types of brain CT pathologies (Table 7).

DISCUSSION

Computerized tomograghy of the brain is a useful tool in demonstrating the anatomical lesion responsible for cerebral-palsied patients' clinical findings (Koch *et al.* 1980; Cohen and Duffner, 1981; Kotlarek *et al.* 1981; Claeys *et al.* 1983). In the previous CT investigations of patients with cerebral palsy, a pathological CT finding has been reported in 68% of patients with congenital cerebral palsy and in 82% of patients with acquired cerebral palsy (Koch *et al.* 1980; Kulakowski and Larroche, 1980). Taudorf and Melchior found that overall sensitivity of CT was 67%(56 out of 83 cases of spastic cerebral palsy children) and Schouman-Claeys *et al.* reported 63%(48 out of 76 cases of cerebral palsy children)(Taudorf and Melchior, 1984: Schouman-Claeys *et al.* 1989). There was no statistically significant difference between the frequencies of pathologic CT findings in the groups with tetraplegia, diplegia and paraplegia, but in the group with hemiplegia, 23 out of 29 patients had pathological CT findings (Taudorf and Melchior, 1984). Koch *et al.* reported patients with hemiplegia had the highest yield of pathological CT findings(16 out of 18 patients)(Koch *et al.* 1980). Wiklund and Uvebrant reported that 62% of patients with hemiplegia had unilateral pathological CT findings located in the hemisphere corresponding to the hemiplegic side and 12% of patients had bilateral lesions(Wiklund and Uvebrant, 1991). In this study, the overall incidence of abnormal CT findings in patients with spastic cerebral palsy was 69.3% and there was no statistically significant difference between the frequencies of pathological CT findings in groups with tetraplegia, diplegia, and hemiplegia. As well, patients with hemiplegia showed the highest frequency of pathological CT findings(11 out of 12

Table 6. MFED total score according to brain CT abnormality

CT Findings	MFED Total Scores	Mean Rank
Bilateral central atrophy	81.3±23.0	44.7
Infarction	70.0±24.5	38.1
Malformation	61.0±22.8	31.7
Bilateral cortical atrophy & Malformation	63.1±27.9	33.9
Bilateral general atrophy	51.9±30.0	26.6
Hemiatrophy	49.0±18.3	22.8
Bilateral cortical atrophy	41.4±31.4	21.1
Bilateral cortical atrophy & Infarction	40.4±22.3	19.1

χ^2=11.23, $p<0.05$

Table 7. Correlation between MFED categories and brain CT findings

Brain CT finding	MFED category						
	GM[1]	FM[2]	P[3]	Sp[4]	SC[5]	So[6]	I[7]
Bilateral atrophy							
cortical	48.79±26.28	44.64±27.38	53.92±30.89	53.14±29.51	57.18±29.76	53.07±28.03	65.20±26.60
central	56.00±29.40	72.71±32.04	74.14±33.27	75.14±34.59	69.86±29.13	79.00±29.41	78.67±7.69
general	47.19±26.51	48.75±27.89	47.24±30.25	46.06±27.86	55.75±27.51	52.69±28.45	55.78±25.25
Infarction	58.09±19.60	61.55±24.45	70.00±26.32	56.64±25.04	70.67±24.66	70.18±21.68	75.00±18.77
Malformation	51.24±27.37	60.06±29.43	64.59±26.93	68.76±26.24	66.44±25.12	69.37±24.74	76.10±22.06
Hemiatrophy	40.80±11.82	47.80±27.48	42.83±27.14	44.83±29.25	44.40±20.38	50.80±25.94	54.33±31.63

[1]: Gross motor, [2]: Fine motor, [3]: Perception, [4]: Speech, [5]: Speech comprehension, [6]: Social, [7]: Independence

cases). These results are very similar to the previous studies.

The most frequent abnormal CT finding was brain atrophy in all types of spastic cerebral palsy. According to Taudorf and Melchior's report, hemiatrophy and infarction were much more frequent in patients with hemiplegia (Taudorf and Melchior, 1984). Jacoby *et al.* reported 4 cases of hemiplegia who had the most impressive CT findings, unilateral loss of cerebral volume with ipsilateral displacement of the midline structures (Jacoby *et al.* 1977). Wiklund and Uvebrant and Wiklund *et al.* reported that the most frequent abnormal CT finding in congenital hemiplegia was periventricular atrophy, which was consistent with a hypoxic-ischemic insult to the immature brain (Wilklund and Uvebrant, 1991; Wilklund *et al.* 1991). In this study, the most frequent pathologic CT finding was bilateral atrophy, which is similar to Wiklund et al.'s result (1991). Taudorf and Melchior reported that 27 out of 83 patients who belonged to the spastic type of cerebral palsy with a mild grade of handicap had normal CT findings (Taudorf and Melchior, 1984). They explained that the structural lesion in these cases may be too small to be visualized by CT or that another possibility may be that the pathology was situated outside the brain. In this study, 30.7% had normal CT findings. It is thought that further study is needed to determine the exact mechanism in patients with spastic cerebral palsy who have a normal CT finding.

CT is a very useful tool in helping the parents visualize the cause of their child's problem in the cases of positive findings on CT. There were several attempts which have been made to correlate CT findings with severity of neurologic impairment (Cohen and Duffner, 1981; Kotlarek *et al.* 1981; Claeys *et al.* 1983; Molteni *et al.* 1987). In Taudorf and Melchior's report, the frequency of pathologic CT increased with the severity of motor handicap in patients with CP ($p<0.05$) and also that the CP children with the lowest IQ had numerically more pathologic CT findings (Taudorf and Melchior, 1984). On the other hand, according to the report of Wiklund and Uvebrant, there was no significant relation between the size of lesion and the severity of motor and other neurologic impairments, although some trends were found that small lesions implied mild to moderate impairments, that large lesions implied moderate to severe impairments and that children with normal CT findings were significantly less impaired (Wiklund and Uvebrant, 1991). However, in previous studies, CT findings were analyzed according to only 3 or 4 levels of motor handicap grade and only 4 levels of IQ grade. Therefore, these studies have some limitation in showing the precise relationship between CT findings and neurological outcome. So in this study, motor and developmental status were measured by MFED score, which has been used for objective and reliable developmental assessment, and the correlation of CT findings with MFED scores was evaluated. A significant difference of MFED score was noted between the group with normal CT findings and the group with pathologic CT findings. The group with pathological CT findings showed a more significant delay in development than the group with normal CT findings.

Wiklund and Uvebrant investigated the CT findings in patients with hemiplegic cerebral palsy and found that adverse developments were associated with a high frequency of arm-dominated hemiplegia and with a wide range of impairment (Wiklund and Uvebrant, 1991). Periventricular atrophy, the most frequent morphological finding, was connected with a large variety of mild and severe impairments. Cortical/subcortical atrophy was correlated with arm-dominated hemiplegia, poor hand function, facial weakness and epilepsy. Kotlarek *et al.* who investigated children with congenital hemiplegia, found a correlation between cortical/subcortical cavities and serious hemiparesis, intellectual impairment and the presence of epilepsy (Kotlarek *et al.* 1980). However, Taudorf and Melchior could not find a correlation between CT findings and clinical parameters. In this study, no significant relationship between specific MFED categories and the types of brain CT pathologies could be established (Taudorf and Melchior, 1984).

Conclusively, the group with pathologial CT findings showed more delay in MFED scores than the group with normal CT findings, although there was no significant relationship between specific MFED categories in development and the type of brain CT pathologies.

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