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The Clock Drawing Test as a General Cognitive Function Screening Tool for Dementia: Quantitative and Qualitative Analyses*

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The present study investigates the usefulness of the Clock Drawing Test(CDT) as a tool for the detection of cognitive impairment by examining the association between CDT performance and, the general cognitive function and each cognitive function evaluated by a neuropsychological battery(SNSB-D). Also, this study examines the efficiency of the CDT for differentiating control, mild cognitive impairment(MCI) and Alzheimer's disease(AD). The results of the quantitative analysis of CDT showed significant mean differences across three groups. In the results of the quality analysis of CDT, errors in all types except for size seem to be different in groups and errors in AD groups appear to be a more frequent than in other groups. We found that the CDT score was significantly correlated with the SNSB-D score. The discriminate accuracy of CDT was relatively low in differentiating the MCI from control group, but somewhat better in differentiating the AD from control group and in differentiating the AD from MCI group. This study showed CDT performance reflects general cognitive function and is a useful tool for assessing cognitive impairment. However, CDT is less adequate at differentiating MCI from control group, so if the CDT is used for MCI, there should be special consideration of this finding, with reference to the quantitative analysis of CDT or other screening tests.

Key words : Clock Drawing Test, Mild cognitive impairment, Dementia, Screening test

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As the population ages, the incidence of mild cognitive impairment(MCI) and dementia increases(Kang, Ha, Kim, Lee, Park, & Lee, 1997; Mashta, 2007; Umidi, Trimarchi, Corsi, Luzzati, & Annoni, 2009). In the case of the Republic of Korea, the incidence of MCI at risk of dementia is estimated to be 24.1%, and the incidence of dementia is 8.4% among people older than 65 years. The number of elderly individuals with dementia has been increasing rapidly, and is estimated to exceed 1,000,000. So it has become important to prevent and manage dementia well(Ministry of Health & Welfare, 2008).

Dementia is a syndrome attributable to illness of the brain, in which there is impairment of attention, orientation, memory, judgment, and language, and it cause impairments of normal activities of daily living(ADL)(Cummings & Benson, 1992; Shankle, Romney, Hara, Fortier, Dick, Chen et al., 2005). Before the progression of dementia, many individuals are in a state between normal aging and dementia. This state is a mild cognitive impairment(MCI), which is often a prodromal stage of Alzheimer's disease (AD)(Flicker, Ferris, & Reisberg, 1991; Gauthier, Reisberg, Zaudig, Petersen, Ritchie, Broich et al., 2006; Peterson, Smith, & Waring, 1999). MCI is characterized to involve a subjective memory complaints and objective cognitive decline, but without normal activities of daily living, and no dementia(Petersen, Doody, Kurz, Mohs, Morris, Rabins et al., 2001). MCI is a risk factor for progression to dementia, particularly of the Alzheimer's disease(Levey, Lah, Goldstein, Steenland, & Bliwise, 2006; Peterson et al., 1999). It is very crucial clinically to screen early state, such as MCI, for decline of cognitive functions because it makes enable appropriate intervention to stop or delay the progression of the disease(Wimo, Winblad, & Grasfstrom, 1999), and could improve the treatment of AD(Peters & Pinto, 2008).

There are many types of cognitive assessments for the identification of cognitive decline caused by mild cognitive impairment and dementia (Levey et al., 2006; Spreen & Strauss, 1998). Because neuropsychological assessment is sensitive enough for early cognitive change(Collie & Maru, 2000), it is useful for assessing cognitive decline and performs well for identifying MCI and dementia(N økleby, Boland, Bergersen, Schanke, Farner, Wagle et al., 2008). However, neuropsychological assessment is lengthy, time-consuming and difficult to carry out(Pinto & Peters, 2009). Therefore, cognitive screening tests that are quick and easy to administer, such as the Mini-Mental State Examination(MMSE) (Folstein, Folstein, & McHugh, 1975), are widely used to identify cognitive decline. The MMSE is a standardized test of cognitive function that takes 10 to 20 min to administer. Because the MMSE is easy to administer and useful for screening, it is the most widely utilized test(Harvan & Cotter, 2006). There are some limitations with the MMSE. The MMSE score is

associated with age and a education level(Bassuk & Murphy, 2003; Braekhus, Laake, & Engdal, 1995) and it is insensitive to visuospatial and executive function(Binetti, Magni, Padovani, Cappa, Bianchetti, & Trabucchi, 1996) and relies more on language(Shulman, 2000).

The Clock Drawing Test(CDT) is another cognitive screening test that involves drawing a clock face, placing all the numbers on the clock, and setting the hands to a specific time(Lezak, 1995). The CDT is less affected by lower education and cultural differences, and it also does not rely as much on language as the other cognitive tests such as the MMSE(Borson, Brush, & Gil, 1999). The CDT requires multiple cognitive functions such as memory, visuoconstructive ability, visual perception, verbal understanding, attention, frontal lobe function, and planning ability(Freedman, Leach, Kaplan, Winocur, Schulman, & Delis, 1994; Kuslansky, Buschke, Katz, Sliwinski, & Lipton, 2002; Royall, Cordes, & Polk, 1998). The CDT measures the visuospatial ability, which is impaired at an early stage of dementia(Schramm, Berger, Muller, Kratzsch, Peters, & Fr ölich, 2002). Also, it is more sensitive for screening cognitive impairment than the MMSE (Hendriksen, Meier, Klitzing, Krebs, Ermini-Fünfschilling, & Stähelin, 1993). Studies have shown associations between the CDT and other cognitive tests, such as the MMSE(Shulman, 2000), CAMCOG memory scale(Cacho, Garcia-Garcia, Fernandez-Calvo, Gamazo, Rodriguez-Peres, Almeida et al., 2005), executive function (Brodaty & Moore, 1997), and the Rey Complex Figure test(Mendez, Ala, & Underwood, 1992). Due to these reasons, the CDT has been proposed as an alternative screening test(Connor, Seward, Bauer, Golden, & Salmon, 2005).

There are some limitations with the CDT studies. A few studies have compared the CDT with neuropsychological battery of higher diagnostic accuracy in dementia. Most studies of the CDT evaluate cognitive function by MMSE without an accurate diagnosis or overall assessment of cognitive function. Many studies have shown a relationship between CDT performance and each cognitive functions not general cognitive function. Because multiple brain regions are combined during CDT performance (Mendez & Cummings, 2003) and the CDT demands an interaction of different cognitive domains(Thomann, Toro, Dos Santos, Essig, & Schr öder, 2008), it should need to confirm the relationship between the degree of general cognitive function and the CDT performance. If there is positive evidence of a relationship between the degree of general cognitive function and CDT performance, then the CDT is a suitable screening test for evaluating general cognitive function.

The aim of the current study is to ascertain the usefulness of the CDT as a tool for the detection of cognitive impairment, investigating the association between CDT performance and, the general and each cognitive function evaluated

by neuropsychological battery. This study also examines the efficiency of the CDT in differentiating normal, mild cognitive impairment and Alzheimer's disease.

METHOD

Participants

Sixty-nine subjects who attended a memory disorder clinic of the Neurology Department at the Asan Medical Center due to their cognitive impairment were included in this study. MRI, laboratory studies, neurologic examination, the Clock Drawing Test(CDT), neuropsychological test, Seoul-Instrumental Activities of Daily Living and Barthel Activity of Daily Living were given to all participants. MRI, laboratory studies, neurologic examination, neuropsychological test, Seoul-Instrumental Activities of Daily Living and Barthel Activity of Daily Living provided information for clinical diagnosis. All subjects were diagnosed by using the individual criteria for each group, control, mild cognitive impairment(MCI) and Alzheimer's disease(AD) by an expert neurologist. Clinical diagnosis of mild cognitive impairment was made according to the criteria for MCI(Petersen et al., 2001). The diagnostic criteria for MCI include an absence of dementia, subjective memory complaints, an objective memory deficit compared with age-appropriate norms, normal general cognitive function, preserved activities of daily living(ADL) and minimal impairment in complex instrumental functions(I-ADL). Alzheimer's disease was diagnosed by DSM-IV and NINCDS-ADRDA criteria(McKhann, Drachman, Folstein, Katzman, Price, & Stadian, 1984). Control subjects had no abnormalities on MRI, laboratory studies, or neurologic examination and no objective cognitive impairments. Of the 69 subjects, twenty were classified with AD, 32 had MCI and 17 were control subjects. The severity of dementia was measured by the clinical dementia rating(CDR) scale(Morris, 1993). In current study, control subjects had a global CDR=0, MCI had a global CDR= 0.5, and AD had a global CDR= 1.

Table 1 shows the mean age, education years

Table 1. Demographic characteristics for each group

Variables		Control(n=17)	MCI(n=32)	AD(n=20)	Total(n=69)
Age(year)		68.47(6.76)	70.81(7.79)	71.60(8.53)	70.46(7.76)
Education(year)		8.97(5.79)	11.00(5.17)	10.23(6.09)	10.28(5.58)
Sex(n)	Male	8(40.0%)	13(40.6%)	7(41.2%)	28(40.6%)
	Female	12(60.0%)	19(59.4%)	10(58.8%)	41(59.4%)

MCI: Mild cognitive impairment; AD: Alzheimer's disease

and sex ratio for each group. The mean age, education and sex were not significantly different between the groups(age: $F(2,66)=.80$, *ns*.; education: $F(2,66)=.73$, *ns*.; sex: $x^2(2) =.005$, $p=.97$) (Table 1).

Materials

Clock Drawing Test(CDT)

The participants were presented with an A4 size blank sheet of paper and a pencil, and the following instructions were given: 'Please draw a clock, put in all the numbers, and set the hands for 10 after 11'. Participants had no time limit and were allowed to make corrections to their drawing. The CDT was scored using the Rouleau scoring system(Rouleau, Salmon, Butters, Kennedy, & McGuire, 1992). The Rouleau scoring system, which consists of a quantitative scoring scale and a qualitative error analysis, has shown high sensitivity, specificity and reliability. The quantitative scoring scale is a 10-point scale that is used to assess the integrity of the clock face(maximum: 2 points), presence and sequence of numbers(maximum: 4 points), and the presence and placement of the hands(maximum: 4 points). A higher level of CDT performance results in a higher score. The qualitative error analysis included (i) abnormal size of the clock; (ii) graphic difficulties, where the error reflects the degree of distortion in the drawing; (iii) stimulus-bound responses, which is the tendency of the drawing to be dominated or guided by a single stimulus; (iv) conceptual deficit, which is an error due to a loss or a deficit of knowledge usually evoked by the word 'clock'; (v) spatial and/or planning deficit, which is suggested by a deficit in the layout of numbers on the clock; and (vi) perseveration, which is defined as the continuation or recurrence of drawing hands or number on the clock. The number of errors was counted independently.

Neuropsychological test

The Seoul Neuropsychological Screening Battery(SNSB)(Kang & Na, 2003) is a structured neuropsychological battery for dementia evaluation and has been used widely in Korea. The SNSB includes tests evaluating attention, language and related functions, visuospatial functions, memory and frontal/executive functions. It has been validated for the Korean population, defining administration and computerized scoring. The Seoul Neuropsychological Screening Battery for Dementia(SNSB-D) has a reduced number of tests to quantify the cognitive domains measured by SNSB. SNSB-D shows the degree of general cognitive function for calculating the total score. It includes the following cognitive domains; attention(17 points), language & related function(27 points), visuospatial function(36 points), memory(150 points) and frontal/executive function(70 points). The possible total score can range from 0 to 300 points. Table 2 shows the SNSB-D sub tests that belong to each cognitive domain.

Table 2. SNSB-D sub tests for each cognitive domain

Cognitive domain	Neuropsychological test
Attention	Digit span: forward / backward
Language and related functions	Korean-Boston Naming Test(K-BNT): Form A Calculation
Visuospatial functions	Rey Complex Figure Test(RCFT) Copy
Memory	Orientation: time and place Seoul Verbal Learning Test(SVLT) : immediate & delayed recall/recognition Rey Complex Figure Test(RCFT) : immediate & delayed recall/recognition
Frontal/ Executive	Impersistence Contrasting programs Go No-Go Test Fist-Edge-Palm Luria loop Controlled Oral Word Association Test(COWAT) : semantic(animal) / phonemic('ㄱ') Korean-Color Word Stroop Test(K-CWST)

Procedure

All participants completed the CDT and the Seoul Neuropsychological Screening Battery for Dementia(SNSB-D). Participants were tested with CDT at the same time or within 6 months following SNSB-D. One licensed clinical psychologist and a graduate student, who were both blinded to the subjects' medical history and group status, scored the CDT. To evaluate inter-rater reliability, 15 CDT scores were randomly chosen and the scores between the two raters were compared. The SNSB-D was conducted to examine general cognitive function of participants and it was evaluated by licensed clinical psychologist who did not know the diagnosis.

Data analysis

Inter-rater reliability was assessed using Pearson correlation coefficients for the quantitative scoring scale and the kappa statistic for the qualitative error analysis. One-way ANOVA was used to study differences between the three groups on CDT quantitative analysis and Neuropsychological Screening Battery for Dementia(SNSB-D) measures. The multi-

dimensional chi-square was conducted to investigate differences in the CDT qualitative analysis among the three groups. Pearson correlation coefficients and Spearman correlation coefficients were calculated to determine the strength of association between the CDT performance and the SNSB-D total and each cognitive domain score. We calculated the cut-off score, sensitivity, specificity and area under curve(AUC) by the receiver operation characteristics(ROC) curves to differentiate the control from MCI groups, the MCI from the AD group, and the AD from the control group. Data analysis was conducted using SPSS 15.0 for Windows.

RESULTS

The inter-rater reliability of Clock Drawing Test scoring

The inter-rater reliability of the CDT quantitative scoring was .91($p<$ .001), indicating excellent reliability. The inter-rater reliability of the qualitative error analysis showed fair to excellent reliability($k=$ 0.89).

Clock Drawing Test quantitative analysis

The quantitative score of CDT was 9.29 ± 0.85 in the control group; 8.16 ± 1.87 in the MCI group; and 5.95 ± 2.06 in the AD group(Fig. 1). The possible total score can range from 0 to 10 points. The results of one-way ANOVA showed significant mean differences across the three groups, $F(2,66)=$ 18.16, $p<$ .001. By post hoc tests, significant CDT mean differences were found between the Control vs. MCI and Control vs. AD groups($p<$ .001), but not between the Control vs. MCI groups,

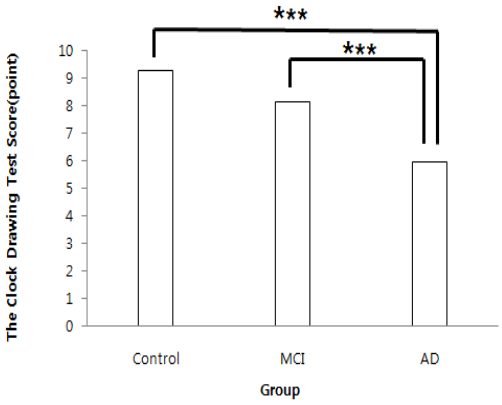

Fig. 1. The quantitative score of Clock Drawing Test for each group
(MCI: Mild cognitive impairment; AD: Alzheimer's disease; *** $p<$ .001)

Table 3. The quantitative analysis of Clock Drawing Test for three groups

	Group			F	Post hoc (Scheffe)
	Control(n=17)	MCI(n=32)	AD(n=20)		
CDT Score	9.29(.85)	8.16(1.87)	5.95(2.06)	18.16*	C, MCI > AD

CDT: Clock Drawing Test; C: Control group; MCI: Mild cognitive impairment; AD: Alzheimer's disease; * $p<$ .05

ns.(Table 3).

Clock Drawing Test qualitative analysis

Only 1 subject in the MCI group showed an error related to the abnormal size of the clock, and there was no difference between groups, $x^2(2)=1.17$, *ns*. Forty-five subjects demonstrated graphic difficulties, with a significant difference between groups, $x^2(2)=20.92$, $p< .05$. The graphic difficulties were classified into mild, moderate, and severe according to distortion. Fifteen subjects were rated as having moderate graphic difficulties, and there was a significant difference between the groups, $x^2(2)=9.44$, $p< .001$. Thirty subjects had mild graphic difficulties and 3 subjects had severe graphic difficulties. There was no significant difference between the groups, respectively, $x^2(2)=.62$, *ns*.; $x^2(2) =.39$, *ns*. Out of all subjects, 17.4% committed stimulus-bound response, and statistically significant differences were found between groups, $x^2(2)=11.23$, $p< .05$. Further, 47.8% of the subjects committed conceptual deficits error, and significant differences were found between groups, $x^2(2)=10.68$, $p< .05$. The frequency of spatial and/or planning deficit was significantly different between groups, $x^2(2)=11.35$, $p< .05$, with about 42% of subjects showing spatial and/or planning deficits. There were no significant differences in the frequency of perseveration, $x^2(2)=1.71$, *ns*.

Neuropsychological test

Significant SNSB-D total score differences were found between the three groups, $F(2, 66)= 32.71$, $p< .001$. One-way ANOVA revealed significant for groups in the SNSB-D cognitive domain scores for Visuospatial, $F(2,66)= 7.96$, $p< .05$, Language, $F(2,66)= 7.07$, $p< .05$, Memory, $F(2,66)= 41.52$, $p< .05$, and Frontal /executive function, $F(2,66)= 16.76$, $p< .05$, but not Attention, $F(2,66)= 0.48$, *ns*. Statistically significant pairwise differences as examined by scheffe post hoc tests were found between the control group and the AD group, with the AD patients performing significantly worse in all tests except attention. In total scores, for Memory and Frontal/Executive, there were significant differences between the MCI and AD group, as well as between the controls and MCI group. In Visuospatial, a post hoc test showed significant differences between the MCI and AD group, but not between the Control and MCI group, indicating the visuospatial ability of the Control group was similar to that of the MCI group. Table 5 shows the scores of the total and cognitive domain from SNSB-D.

Correlations Between Clock Drawing Test and Neuropsychological test

Correlations between Clock Drawing Test quantitative score and SNSB-D score

We calculated Pearson's correlation between

Table 5. Mean and standard deviations on SNSB-D in three groups

	Group			*F*	Post hoc (Scheffe)
	Control(n=17)	MCI(n=32)	AD(n=20)		
Attention	9.41(1.80)	9.28(1.99)	8.80(2.40)	.48	ns
Visuospatial	31.68(3.82)	31.48(4.44)	25.68(7.89)	7.96*	C, MCI > AD
Language	22.76(4.34)	20.03(4.85)	16.65(5.62)	7.07*	C > AD
Memory	84.26(15.83)	59.53(21.64)	31.48(10.34)	41.52*	C > MCI > AD
Frontal/Executive	53.59(8.23)	43.88(12.56)	31.65(12.33)	16.76*	C > MCI > AD
SNSB-D Total	201.71(28.53)	164.19(37.19)	114.25(29.61)	32.71*	C > MCI > AD

C: Control group; MCI: Mild cognitive impairment; AD: Alzheimer's disease; * $p < .05$

CDT scores and the scores from SNSB-D. The Pearson correlation coefficient between CDT scores and total score, measuring general cognitive function, was .65($p < .01$). Table 6 shows that the CDT score was significantly correlated with all cognitive domains from SNSB-D. CDT score showed medium size correlation(r=0.2-0.4) with Attention, and CDT score showed strong correlation(r=0.4-0.7) with Visuospatial function, Language, Memory, Frontal /Executive, SNSB-D Total score.

To examine the specific relationship between the CDT scores and Memory and Frontal /Executive function, additional correlation analysis was carried out(Table 6). Memory was subdivided into Verbal Memory and Visual Memory. Frontal/Executive function was subdivided into Behavioral execution, which was consist of Impersistence, Contrasting programs, Go No-Go Test, Fist-Edge-Palm, and Conceptual flexibility, which was measured by COWAT. CDT score was significantly strong correlated with Verbal Memory, Visual Memory, Behavioral execution and Conceptual flexibility.

Correlations between the frequency of Clock Drawing Test qualitative error and SNSB-D score

Spearman's correlation was used to evaluate correlation between the frequency of CDT error and the SNSB-D score. The frequency of error types such as Graphic difficulties, Stimulus-bound response, Conceptual deficits, Spatial and/or planning deficit, and Perseveration, were significantly and negatively correlated with the total score from the SNSB-D(Graphic difficulties: r= -.62, $p < .01$; Stimulus-bound response: r= -.38, $p < .01$; Conceptual deficits: r= -.50, $p < .01$; Spatial and/or planning deficit: r= -.42, $p < .01$; Perseveration: r= -.36, $p < .01$). Table 6 shows that correlation between the frequency of error types and the cognitive domain from

SNSB-D. The frequency of Graphic difficulties showed medium size correlation with Attention, and strong correlation with Visuospatial function, Language, Memory, Frontal/Executive, and SNSB -D Total score. The frequency of Stimulus-bound response showed medium size correlation with Visuospatial function, Memory, Frontal/Executive and SNSB-D Total score, and strong correlation with Language. The frequency of Conceptual deficits showed medium size correlation with Attention and Visuospatial function, and strong correlation with Language, Frontal/Executive, and SNSB-D Total score. The frequency of Spatial and/or planning deficit showed medium size correlation with Attention, Visuospatial function, Language, Memory and Frontal/Executive and strong correlation with SNSB-D Total score. The frequency of Perseveration showed medium size correlation with Visuospatial function, Language, Memory, Frontal/Executive, and SNSB-D Total score. The frequency of size error was not significantly correlated with total and cognitive domain score from SNSB-D.

To examine the specific relationship between the CDT error and Memory and Frontal/ Executive function, additional correlation analysis was conducted(Table 6). The frequency of error types such as Graphic difficulties, Conceptual deficits, Spatial and/or planning deficit, and Perseveration, were significantly and negatively correlated with Verbal Memory and Visual Memory. Also, Visual Memory was highly correlated with these error types than Verbal Memory. The frequency of error types such as

Table 6. Correlation coefficient between CDT and SNSB-D

	A	V	L	M	VerbalM	VisualM	F/E	BE	CF	Total
CDT score†	.39**	.58**	.67**	.51**	.45**	.47**	.62**	.49**	.46**	.65**
Size‡	-.19	-.06	-.19	-.08	-.17	.00	-.17	-.01	-.11	-.15
GD‡	-.30*	-.49**	-.55**	-.54**	-.41**	-.53**	-.56**	-.40**	-.47**	-.62**
SBR‡	-.03	-.30*	-.43**	-.30*	-.29*	-.26*	-.36**	-.31**	-.24**	-.38**
CD‡	-.29*	-.40**	-.54**	-.39**	-.32**	-.37**	-.50**	-.36**	-.41**	-.50**
SPD‡	-.28*	-.40**	-.38**	-.39**	-.25*	-.39*	-.33**	-.24*	-.23	-.42**
PE‡	-.08	-.26*	-.25*	-.38**	-.31**	-.38**	-.34**	-.18	-.32**	-.36**

CDT: Clock Drawing Test; A: Attention; V: Visuospatial; L: Language; M: Memory; Verbal M: Verbal Memory; Visual M: Visual Memory; F/E: Frontal/Executive; BE: Behavioral execution; CF: Conceptual flexibility; Total: SNSB -D total score; GD: Graphic difficulties; SBR: Stimulus-bound response; CD: Conceptual deficits; SPD: Spatial and/or planning deficit; PE: Perseveration; † Pearson's correlation coefficient; ‡ Spearman's correlation coefficient; * $p < .05$; ** $p < .01$

Graphic difficulties, Stimulus-bound response, and Conceptual deficits were significantly and negatively correlated with Behavioral execution and Conceptual flexibility. The frequency of Spatial and/or planning deficit showed medium size correlation with Behavioral execution. The frequency of Perseveration showed medium size correlation with Conceptual flexibility. The frequency of size error was not significantly correlated with Verbal Memory, Visual Memory, Behavioral execution and Conceptual flexibility.

The efficiency of Clock Drawing Test for differentiation of one group from another

Sensitivity and specificity for the CDT scores were obtained using ROC analysis(Table 7). When differentiating the MCI from control group, the CDT score had a cut-off of 8.5, a sensitivity of 43.7%, and a specificity of 88.2%, while the area under the ROC curve was .689 and SE was .08($p<$ .05). In order to differentiate the control from AD groups, the CDT score had a cut-off value of 8.5, a sensitivity of 88.2%, and a specificity of 90%, while the area under the ROC curve was .951 and SE was .03($p<$ .05). When differentiating the MCI from AD groups, the CDT score had a cut-off score of 7.5, a sensitivity of 75%, and a specificity of 80%, while the area under the ROC curve was .802 and SE was .06($p<$ .05). The AUC represents predictive accuracy. Considering the AUC, CDT had a poor predictive accuracy in discriminating Control from MCI, but the CDT showed good predictive accuracy in discriminating Control from AD groups and AD from MCI groups. The ROC curves for the CDT are shown in Fig. 2, 3, and 4.

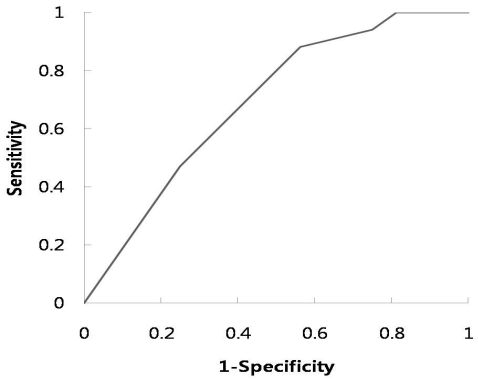

Fig. 2. ROC curve by CDT for differentiation Control vs. MCI
(ROC: Receiver operation characteristics curves; CDT: Clock drawing test; MCI: Mild cognitive impairment)

Table 7. AUC, sensitivity, specificity and cut-off score of the CDT

	AUC	CI(AUC, 95%)	Sensitivity(%)	Specificity(%)	Cut-off score
Control vs. MCI	.689	.541-.838	88.2	43.7	8.5
Control vs. AD	.951	.889-.983	88.2	90.0	8.5
MCI vs. AD	.802	.682-.921	75.0	80.0	7.5

MCI: Mild cognitive impairment; AD: Alzheimer's disease; AUC: Area Under Curve; CI: confidence interval

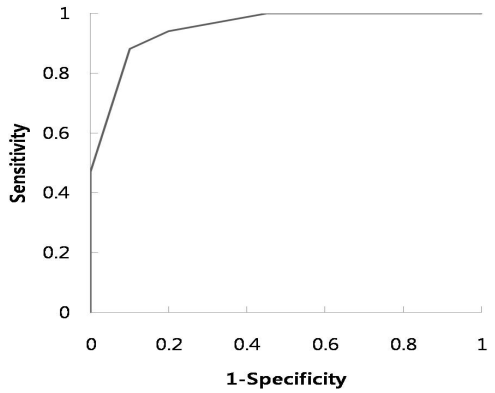

Fig. 3. ROC curve by CDT for differentiation Control vs. AD

(ROC: Receiver operation characteristics curves; CDT: Clock drawing test; AD: Alzheimer's disease)

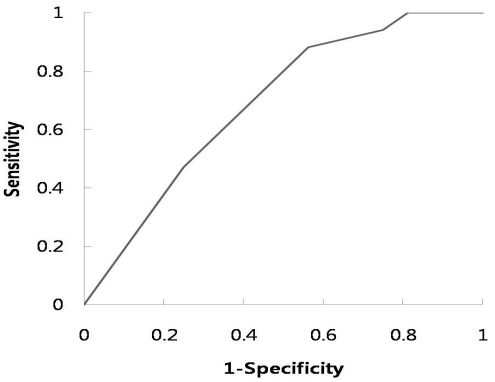

Fig. 4. ROC curve by CDT for differentiation MCI vs. AD

(ROC: Receiver operation characteristics curves; CDT: Clock drawing test; MCI: Mild cognitive impairment; AD: Alzheimer's disease)

DISCUSSION

The aim of the this study is to investigate the usefulness of the Clock Drawing Test(CDT) as a tool for the detection of cognitive impairment by examining the association between CDT performance and the degree of general cognitive function evaluated by a neuropsychological battery(SNSB-D). Also, this study investigates the correlation between CDT performance and cognitive functions, such as attention, memory, visuospatial ability, language, frontal lobe function, in order to study how the CDT reflects cognitive function. Finally, this study examines the efficiency of the CDT for differentiating control, mild cognitive impairment(MCI) and Alzheimer's disease(AD).

In order to find out if CDT effectively measures general cognitive functions, we examined the relationship with CDT performance and SNSB-D score that estimates general cognitive function. The results revealed that the CDT score was significantly correlated with the SNSB-D score, suggesting that CDT is a useful tool that reflects general cognitive functions. In addition, the positive correlation between all the domains in SNSB-D and CDT is significant, supporting arguments that CDT requires varied cognitive abilities(Freedman et al., 1994; Kuslansky et al., 2002; Royall et al., 1998). After investigating the relationship between SNSB-D and CDT in terms of frequency of errors, it turns out that all the errors, except size errors, appear to have a negative correlation with the general cognitive function and domains in SNSB-D. This finding suggests that the low quality of CDT is related to poor cognitive

function. Additionally, Visual Memory was negative and highly correlated with the frequency of error types such as Graphic difficulties, Conceptual deficits, Spatial and/or planning deficit, and Perseveration than Verbal Memory. These result indicated that the low quality of CDT is related to poor Visual Memory.

To investigate the efficiency of CDT as a tool for differentiating groups, we examined the sensitivity, specificity, and AUC of the CDT scores by ROC analysis. When differentiating the AD from control groups, the CDT score had a sensitivity of 88.2%, a specificity of 90%, and an AUC of .951. When differentiating the AD from MCI groups, the CDT score had a sensitivity of 75%, a specificity of 80%, and an AUC of .802. The results indicate that the CDT score is adequate for differentiating AD from control and MCI groups. However, when differentiating the MCI from control groups, the CDT score had a sensitivity of 43.7%, a specificity of 88.2%, and an AUC of .689. Considering the low sensitivity and AUC, this result suggests that CDT is less adequate at differentiating MCI from control groups. Other previous studies(e. g. Chiu, Li, Lin, Chiu, & Liu, 2008; Connor et al., 2005; Powlishta, Dras, & Stanford, 2002) have reported similar result. So if the CDT is used for MCI, there should be special consideration of this finding, with reference to the quantitative analysis of CDT or other screening tests.

In current study, the inter-rater reliability of the CDT scoring was high. The inter-rater reliability of the CDT quantitative scoring was .91 and of the CDT qualitative scoring was .89. This result indicates that the CDT scoring system is reliable. The results of the quantitative analysis of CDT showed significant mean differences across three groups. The control group performance was the best, MCI group performance was the second, and AD group performance was the worst. After comparing these three group performances, it turns out that the control and MCI group performances were much better than AD performance, and the control and MCI group performances were not particularly distinguished. This result seems to reflect that the quantitative score of CDT in the MCI group had high variability and that MCI, unlike AD, had less severe and widespread cognitive deficits(Gauthier et al., 2006). However, when comparing the mean CDT scores of the cognitively normal subjects with the scores of MCI, none of th e studies could identify significant differences(Beinhoff et al., 2005; Nunes et al., 2008). These results should still be considered with caution. The finding of AD performance inferiority to control and MCI performances seems to be the same as findings from previous studies(e.g. Libon, Malamut, Swenson, Sands, & Cloud, 1996; Rouleau et al., 1992) on dementia patients using CDT.

In the results of the quality analysis of CDT, errors in all types except for size seem to be

different in groups and errors in AD groups appear to be a more frequent than in other groups. This implies that the quality of AD performance is also low, in comparison to other groups. AD groups had more conceptual deficit errors than any other group, and it means there are deficits in the semantic knowledge of the clock(Rouleau et al., 1992). The MCI and AD group showed conceptual deficits and spatial and/or planning deficits most frequently. This result is consistent with those of previous studies (e.g.,, Chiu et al., 2008; Kitabayashi, Ueda, Narumoto, Nakamura, Kita, & Fukui, 2001). And these results suggest that semantic impairments related to a clock and frontal executive and visuospatial impairments play a role in poor performance of AD, even in the early stage of this disease(Kitabayashi et al., 2001). Furthermore, among error types, graphic difficulties were generally often seen in normal individuals(Kim, 2002).

This current study assessed the extent of general cognitive functions using SNSB-D, which is a structured neuropsychological battery for dementia evaluation, in clinically defined MCI, AD, and control cases. Also, this study investigated how CDT performance reflects general cognitive function and determined that CDT is a useful tool for assessing cognitive impairment. We were also able to ascertain that CDT is an economical test in terms of time and price and its performance is as good as those of existing cognitive screening tests. In previous studies, the qualitative analysis of CDT was done less than the quantity analysis of CDT. This study demonstrated which cognitive impairments showed quality errors through the qualitative analysis.

The following limitations of this study should be used to guide the design of future studies. First, the numbers of participants in the three groups for this study were too small to allow for a generalization of the results. In later studies, the number of participants should be increased to enable generalization of results. Second, The proportion of control subject to MCI and AD in this study isn't the same as that in the Republic of Korea. Each group should be consisted of by considering the prevalence in later studies. Third, the inter-rater reliability of the CDT scoring was high in the current study, but their vague rating standards, which were often irrelevant errors in the study, caused a lot of complications. The rating standards o f CDT are objectified, but it is necessary to specify the standards and have the raters practice rating in order to prevent inconsistency. Finally, it is necessary to have various types of dementia patients as subjects and to observe errors and performance patterns in order to achieve more clinical usefulness. Further, both quantitative analysis and qualitative aspects of CDT performance are needed. Also, with the additional results from a qualitative analysis, we may be able to extend the usefulness of CDT as a screening tool for

different types of dementia.

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치매 선별 검사로서 시계그리기 검사의 일반 인지기능 선별력: 양적 분석과 질적 분석을 중심으로

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본 연구는 신경심리학적 배터리(SNSB-D)에 의해 측정된 전반적인 인지기능 및 기억력, 시공간 기능 등의 세부 인지기능과 시계 그리기 검사수행의 관계를 확인함으로써 인지기능 저하를 탐지하는 도구로서 시계 그리기 검사의 유용성을 확인하였다. 또한 통제집단, 경도인지장애, 그리고 알츠하이머형 치매를 변별하는데 있어 시계 그리기 검사의 효율성을 확인하였다. 통제집단 17명, 경도인지장애 집단 32명, 그리고 알츠하이머형 치매집단 20명이 연구에 참여하였으며 모두 시계 그리기 검사와 SNSB-D 검사를 수행하였다. 시계 그리기 검사의 양적 분석결과, 세 집단 간 유의미한 평균차이를 보였으며 사후분석에서 통제집단과 경도인지장애 집단의 차이는 유의미하지 않았다. 시계 그리기 검사의 질적 분석결과, 크기 오류를 제외하고 모든 오류 유형에서 세 집단 간 차이를 보였으며 알츠하이머형 치매집단이 다른 집단보다 더 많은 빈도오류를 보였다. 시계 그리기 검사의 양적 점수는 SNSB-D에 의해 측정된 전반적인 인지기능 및 각 세부 인지기능과 유의미한 정적 상관을 보였으며, 시계 그리기 검사의 오류 빈도는 전반적인 인지기능 및 세부 인지 기능의 점수와 부적 상관을 보였다. 결론적으로, 시계 그리기 검사는 통제집단과 경도인지장애 집단으로 부터 알츠하이머형 치매집단을 잘 변별하였으나 통제집단과 경도인지장애 집단을 잘 변별하지는 못하였다. 본 연구는 시계 그리기 검사가 전반적인 인지기능을 반영하고 인지기능 저하를 탐지하는데 유용한 도구임을 입증하였으나, 통제집단과 경도인지장애 집단을 변별하는 데는 예민하지 않으므로, 경도인지장애 집단에게 적용할 때에는 시계 그리기 검사의 질적 분석이나 다른 인지기능 측정검사로 보완하는 것이 필요하다.

주요어 : 시계 그리기 검사, 경도인지장애, 치매, 선별 검사