Diagnostic performance of the Clock Drawing Test using a pre-drawn circle in persons with early dementia

ORIGINAL ARTICLE

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ABSTRACT

Background. The Clock Drawing Test (CDT) is a cognitive screening tool applicable across different cultures and languages. We examined its diagnostic performance in detecting persons with early dementia using comprehensive and abbreviated scoring methods with a pre-drawn circle and evaluated the influence of prior education.

Methods. A cross-sectional study was performed for 13 cognitively intact and 55 early dementia subjects attending a memory clinic in Singapore. The clock drawings were scored according to comprehensive (Lin's 16-item clock drawing and clock copying) and abbreviated (Lin's simplified, Watson, Schulman) protocols. Diagnostic performance and optimal cut-off scores were determined, using receiver operating characteristic curves, stratified by educational level and compared with quoted cut-off scores.

Results. Comprehensive protocols outperformed abbreviated protocols, with the area under the curve being 0.87 to 0.91, sensitivity being 69.2 to 76.9%, and specificity being 83.6 to 96.4%. Higher optimal cut-off scores were required compared to the original cut-off scores for all CDT methods. Educational level influenced the optimal cut-off scores in the comprehensive but not the abbreviated CDT method. The diagnostic performance of the CDT using a pre-drawn circle was superior in subjects with ≤6 years of education.

Conclusion. CDT using a pre-drawn circle has good diagnostic performance in detecting persons with early dementia, particularly in persons with lower educational levels. Cut-off scores should be adjusted to reflect the early stage of dementia and the educational level.

Key words: Asian continental ancestry group; Cognitive science; Dementia

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INTRODUCTION

The prevalence of dementia increases because of ageing populations.[1] An accurate cognitive screening tool for detecting early dementia is required to complement strategies in developing disease-specific biomarkers and treatment. The ideal cognitive screening test should be quick and easy to administer, require minimal training for the assessor, and not involve specialist equipment. It should be reliable and able to demonstrate good diagnostic capability with high sensitivity and specificity. The test should be acceptable to older persons and unaffected by their language, culture and educational level.

Most cognitive assessment tools have been developed in relatively homogenous western

populations. Subjects with low levels of education tend to have worse scores on cognitive testing, particularly if not conducted in their native language.[2] This poses a challenge for Asian populations where many diverse ethnic groups co-exist and speak different languages and dialects. Furthermore, there is considerable variation in educational attainment among older people; levels achieved are generally lower in females and in rural areas. In Singapore, 66% of people aged >65 years and 76% of those aged >75 years have no formal education.[3] In contrast, 95% of Japanese people aged >65 years completed at least primary education, of whom a third completed secondary education.[4] Therefore, any cognitive screening test used in Asian populations should attempt to minimise bias due to education.

The Clock Drawing Test (CDT) is a brief cognitive test that assesses multiple cognitive domains including comprehension, planning ability, executive functioning, visual memory and reconstruction, visuospatial ability and numerical knowledge (**Figure**).[5] It is simple and quick to administer and can also be applied across different cultures and languages.[6] Older people may find the test less threatening and more acceptable. Several studies have found CDT scores to correlate with educational levels.[6-8] Inferior performance on the CDT among illiterate subjects may reflect their being less adept at pen-holding, writing and drawing skills rather than any actual cognitive impairment. Similarly, subjects might be disadvantaged and their CDT scores become compromised if they start off with a poorly drawn circle due to poor pen-holding skills or other problems (tremor or arthritic hands). The use of a pre-drawn circle may overcome this bias, as it is uncertain whether the omission of the circle-drawing step might attenuate the diagnostic utility of the CDT.

One limitation of the CDT is the lack of a universal scoring system. A review of 16 different CDT methods reported variations in the instructions such as time setting, copying and time-reading commands, as well as the use of a pre-drawn circle.[9] Scoring methods also range from comprehensive 20-item scales[10] to the shorter 4-anchored point CERAD scale.[6] Comparisons are difficult to make, as studies differ in their population samples. Validation studies in Asian populations have shown good diagnostic utility with most CDT methods using a pre-drawn circle (**Table 1**). However, few studies have focused on the use of the CDT in persons with early dementia[8,11] and the impact of education on CDT scores.[8,12]

The aims of this study were (1) to examine the diagnostic performance of the CDT in detecting early dementia in our local population using comprehensive and abbreviated scoring methods with a pre-drawn circle, (2) to evaluate the influence of education on the performance and optimal cut-off scores for each scoring method, and (3) to determine the correlation of CDT scores with the Chinese Mini-

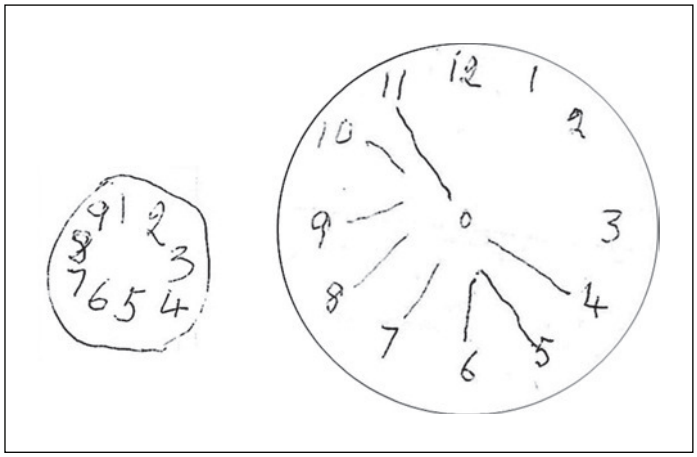

Figure. A freely drawn clock (left) and a clock completed with a pre-drawn circle (right). With many clock drawing test (CDT) scoring protocols emphasising the correct placement of the number 12 and equal spacing of clock numerals, this subject is disadvantaged by his poorly drawn small circle, resulting in a worse CDT score.

Mental State Examination (CMMSE).[13]

METHODS

Study design and subjects

This cross-sectional study comprised patients attending the Memory Clinic, Tan Tock Seng Hospital, Singapore between January and December 2006. The clinic provides subspecialty services in a tertiary teaching hospital and accepts referrals from primary care physicians and hospital doctors for evaluation and management of memory disorders. The sample included cognitively intact subjects and subjects with early dementia who fulfilled the Diagnostic and Statistical Manual of Mental Disorders, fourth edition (DSM-IV) criteria[14] with Clinical Dementia Rating (CDR)[15] score of 0.5 to 1.0. As our study focused on detecting early dementia, subjects with mild cognitive impairment were excluded, as were subjects with moderate-to-severe dementia (CDR>1.0) and those unable to perform the CDT. Data for this study were extracted from a database for which approval was obtained from the Institutional Review Board of National Healthcare Group Singapore.

Assessment and diagnosis

All subjects underwent standardised clinical assessment by a consultant geriatrician and a nurse clinician, as well as neuroimaging and relevant blood investigations. Mood was assessed using the Cornell Scale for Depression in Dementia (CSDD).[16] A clinical psychologist conducted validated neuropsychological tests to assess domains of verbal memory, language, visuospatial abilities, and executive functioning.[17] Cognitive screening tests included the 10-item Abbreviated Mental Test (AMT)[18] and 28-item CMMSE, both modified to adapt to the local context as described in a previous validation study.[19] Thereafter, a consensus meeting was held to determine the final diagnosis. The diagnosis of dementia was made if subjects fulfilled DSM-IV criteria. Aetiology of dementia was determined using guidelines of the National Institute of Neurological and Communicative Disorders and Stroke and the Alzheimer Disease and Related Disorder Association[20] for possible Alzheimer's dementia, National Institute of Neurological Disorders and Stroke and Association Internationale pour la Recherche et l'Enseignement en Neurosciences[21] for possible vascular dementia, plus other dementias using standardised criteria. Severity of dementia was classified according to the validated CDR scale.[22]

Clock Drawing Test

Subjects were asked to draw a clock on a pre-drawn circle (8 cm in diameter), setting the time to 11:10. They were then asked to copy a printed clock on another pre-drawn circle below the first clock. There was no time restriction and instructions were repeated if the subject could not understand the

Table 1
Studies using the Clock Drawing Test for detecting dementia in Asian population

Study	No. of cases/ controls	Clock Drawing Test	Pre-drawn circle	Sensitivity (%)	Specificity (%)	Area under curve
Lam et al[28]	53/53	Lam clock drawing	Yes	83	79	-
Chan et al[29]	51/34	Lam clock drawing	Yes	89	47	0.81
Leung et al[8]	66/66	Lam clock drawing	Yes	79	64	-
Leung et al[8]	66/66	Lam clock copying	Yes	76	74	-
Jitapunkul et al[30]	12/36	Chula Clock Drawing Scoring System	Yes	100	94	-
Kanchanatawan et al[31]	25/644	Chula Clock Drawing Scoring System	Yes	88	74	0.91
Lin et al[23]	144/259	Lin clock drawing	Yes	67	75	0.74
Lin et al[23]	144/259	Lin clock copying	Yes	51	74	-
Lin et al[23]	144/259	Lin simplified	Yes	73	66	0.74
Yap et al[12]	73/75	CLOX 1 (clock drawing)	No	75	76	0.84
Yap et al[12]	73/75	CLOX 2 (clock copying)	No	75	80	0.85
Chiu et al[11]	40/76	Rouleau clock drawing	No	60	72	0.72
Chiu et al[11]	40/76	Rouleau clock copying	Yes	58	85	0.73

request.

We selected 5 scoring protocols that use a pre-drawn circle. The comprehensive scoring system[23] for clock drawing and clock copying consisted of 16 items with cut-off scores for dementia of <11 for clock drawing and <13 for clock copying. The abbreviated scoring systems consisted of Lin's simplified scoring method,[23] Watson,[24] and Schulman[25] protocols. Lin's simplified method consisted of 3 items where a point was given for the correct placement of the number 12, the hour hand, and the minute hand being longer than the hour hand. In the Watson protocol, the clock was divided into 4 equal quadrants and each quadrant should contain 3 digits. A point was given for any errors in the first 3 quadrants, whereas error in the last quadrant was given 3 points. A score of >3 was considered positive for dementia. The Schulman protocol was a 6-point global rating scale where 5 points were given for a 'perfect' clock and zero for inability to make any reasonable representation of a clock.

Clocks were scored by 3 independent raters blinded to the diagnosis, AMT and CMMSE scores. The first rater scored clocks according to Lin's comprehensive scoring system, whereas the second rater used Lin's 3-item simplified method and the Watson protocol. The third rater scored clocks according to the Schulman protocol.

Statistical analysis

Continuous variables were analysed using the *t*-test, whereas categorical variables were analysed using the Chi-squared test. A p value of <0.05 was considered statistically significant. Sensitivity, specificity, and optimal cut-off scores were determined using the receiver operating characteristic curve (ROC).

Table 2
Cognitive performance of cognitively intact and early dementia subjects*

Parameter	Cognitively intact subjects	Early dementia subjects	p Value
No. of subjects	13	23 (CDR=0.5) & 32 (CDR=1.0)	-
Age (years)	71.5±9.7 (56-88)	76.8±6.0 (59-91)	0.015
Gender			0.296
Male	6 (46)	17 (31)	
Female	7 (54)	38 (69)	
Race			0.212
Chinese	13 (100)	49 (89)	
Others	0 (0)	6 (11)	
Years of education	10.3±4.2 (3-17)	4.7±4.1 (0-14)	<0.001
Cornell Scale for Depression in Dementia score	6.23±4.9	6.13±4.9	0.946
Aetiology			
Alzheimer's disease	-	24 (43.6)	-
Vascular dementia	-	13 (23.6)	-
Mixed dementia	-	14 (25.5)	-
Other dementia	-	4 (7.3)	-
Test scores (range)			
Abbreviated Mental Test (0-10)	9.3±1.2	6.5±1.7	<0.001
Chinese Mini-Mental State Examination (0-28)	25.9±2.1	18.2±3.8	<0.001
Clock Drawing Test scores (range)			
Lin clock drawing (0-16)	14.3±1.7	9.4±3.9	<0.001
Lin clock copying (0-16)	14.7±1.4	10.9±3.0	<0.001
Lin simplified (0-3)	2.9±0.4	2.1±1.5	0.086
Watson (0-7)	1.2±2.1	3.4±2.8	0.009
Schulman (0-5)	4.7±0.6	3.3±1.4	0.001

* Data are presented as no. (%) or mean±SD (range)

We compared the area under the curve (AUC) of the various ROCs as a summary statistic for the diagnostic test performance of the different scoring methods. Educational level was stratified according to ≤6 years and >6 years of education. Pearson's partial correlation with CMMSE scores was calculated adjusting for age and education.

RESULTS

Baseline characteristics and cognitive tests scores

13 cognitively intact subjects and 55 subjects with early dementia (CDR 0.5 in 23 and CDR 1.0 in 32) were included. 91% of the subjects were ethnic Chinese. Predominant aetiologies were Alzheimer's disease (44%), vascular dementia (24%), and mixed dementia (26%). Compared with cognitively intact subjects, subjects with early dementia were significantly older (76.8 vs. 71.5 years, p<0.05, **Table 2**) and had fewer years of formal education (4.7 vs. 10.3 years, p<0.05, **Table 2**). They also had significantly worse scores for AMT, CMMSE and CDT, apart from Lin's 3-item simplified method. There was no significant difference in CSDD scores.

Performance of cognitive tests

The CDT demonstrated good diagnostic utility for detecting early dementia, despite not superior to the AMT and CMMSE for which AUCs were 0.92 and 0.96, respectively (**Table 3**). Among various CDT scoring methods, the comprehensive scoring methods for clock drawing (AUC=0.87) and clock copying (AUC=0.91) had best performance. Among

Table 3
Performance of cognitive tests using optimal cut-off scores

Test	Quoted cut-off	Optimal cut-off	Sensitivity (%)	Specificity (%)	Area under curve (95% CI)	LR+	LR-
Abbreviated Mental Test	<8	<9	84.6	87.3	0.92 (0.82-1.00)	6.66	0.18
Chinese Mini-Mental State Examination	<21	<24	84.6	92.7	0.96 (0.91-1.00)	11.59	0.17
Lin clock drawing	<11	<14	76.9	83.6	0.87 (0.78-0.96)	4.69	0.28
Lin clock copying	<13	<15	69.2	96.4	0.91 (0.81-1.00)	19.22	0.32
Lin simplified	<3	<3	84.6	65.5	0.77 (0.65-0.89)	2.45	0.24
Watson	>3	>1	72.7	69.2	0.74 (0.60-0.88)	2.36	0.39
Schulman	<4	<5	76.9	72.7	0.79 (0.68-0.91)	2.82	0.32

Table 4
Diagnostic performance, optimal cut-off, and mean scores of cognitive tests stratified by education

Test	Quoted cut-off	≤6 years of education (n=42)					>6 years of education (n=13)				
		Mean± SD scores	Optimal cut-off	Sensitivity (%)	Specificity (%)	Area under curve (95% CI)	Mean± SD scores	Optimal cut-off	Sensitivity (%)	Specificity (%)	Area under curve (95% CI)
Abbreviated Mental Test	<8	6.2±1.7	<9	84.6	90.5	0.93 (0.81-1.00)	7.2±1.5	<9	84.6	76.9	0.89 (0.00-1.00)
Chinese Mini-Mental State Examination	<21	17.3±3.7*	<23	92.3	90.5	0.97 (0.00-1.00)	21.0±2.8	<24	84.6	92.3	0.92 (0.00-1.00)
Lin clock drawing	<11	8.6±3.9*	<12	92.3	73.8	0.90 (0.82-0.98)	12.2±2.6	<14	76.9	69.2	0.76 (0.57-0.95)
Lin clock copying	<13	10.4±3.1*	<14	84.6	85.7	0.93 (0.81-1.00)	12.7±1.5	<15	69.2	84.6	0.84 (0.69-0.99)
Lin simplified	<3	2.0±1.7	<3	84.6	69	0.79 (0.67-0.91)	2.5±0.5	<3	84.6	53.8	0.69 (0.48-0.90)
Watson	>3	3.8±2.9	>1	73.8	69.2	0.76 (0.63-0.90)	2.1±2.3	>1	69.2	69.2	0.66 (0.45-0.88)
Schulman	<4	3.1±1.3*	<5	76.9	81	0.84 (0.74-0.95)	4.2±1.1	<5	76.9	46.2	0.63 (0.41-0.85)

* p<0.05, comparing 2 educational groups

abbreviated protocols, the Schulman method performed best (AUC=0.79). Optimal cut-off scores were higher compared to values quoted in original reference studies for the AMT, CMMSE and CDT by all scoring methods apart from Lin's simplified 3-item method.

Influence of education

When stratified by educational level, mean scores for the CMMSE and CDT by Lin's comprehensive scoring systems and Schulman method were significantly higher in those with >6 years of education (**Table 4**). The diagnostic performance for all the cognitive tests was superior in subjects with ≤6 years of education, with consistently higher AUC and similar or better sensitivity and specificity. When comparing the 2 educational groups, larger differences in AUCs were found for the CDT (ΔAUC=0.09-0.21) compared to the CMMSE (ΔAUC=0.05) and AMT (ΔAUC=0.04). The difference in AUC was highest for the Schulman method (ΔAUC=0.21).

Lower optimal cut-off scores were found in subjects with ≤6 years of education for the comprehensive scoring protocols for clock drawing (<12 vs. <14) and clock copying (<14 vs. <15), but not the abbreviated scoring methods. However, these cut-off scores were still higher than the original cut-off scores quoted in the reference studies.

There were no significant differences in age, gender, CDR score or aetiology of dementia between the 2 educational groups to account for the differences in CDT performance.

Correlation with CMMSE

The CDT had moderately good correlation with CMMSE scores even after adjusting for age and education. Pearson correlation was best for the Schulman method (0.54, $p<0.001$) and Lin's comprehensive scoring method for clock drawing and clock copying (0.51 and 0.50 respectively, $p<0.001$). Pearson correlation for the Watson method was -0.36 ($p<0.05$) while correlation for Lin's 3-item simplified method was poor at 0.07 ($p=0.57$).

DISCUSSION

In our study, CDT has good diagnostic utility particularly with the comprehensive scoring methods. The correlation with CMMSE scores was comparable to previous studies.[10,26] The sensitivity, specificity, and AUC for all CDT methods were higher compared to those in another Asian study focusing on early dementia.[11] The AUCs of the comprehensive methods were also comparable to those of an earlier Singaporean study,[12] although their study included subjects with mild-and-moderate dementia and the CDT protocol used was CLOX,[27] which does not use a pre-drawn circle. The use of a pre-drawn circle in our study and other studies[28-31] did not result in inferior performance of the CDT.

Our results suggested the modulation of diagnostic performance by educational attainment (**Table 4**). When comparing subjects with early dementia stratified by educational level, differences in AUCs were larger in the CDT than the CMMSE and AMT, indicating a greater influence of educational attainment on CDT performance. Differences in sensitivities were larger in the CDT than the MMSE.[6] In our study, the Schulman method appeared particularly vulnerable to the effect of education. Its diagnostic performance was the best among the abbreviated methods for the overall study and in subjects with ≤6 years of education, yet it was the worst performing CDT scoring method in those with >6 years of education. The difference in AUC between the 2 educational groups was also highest for the Schulman method.

In our subjects, the optimal cut-off scores were higher despite fewer years of education. Our study focused exclusively on subjects with early dementia; whereas the original study[23] included dementia subjects with CDR 1, 2 and 3, and the control group included CDR 0.5 subjects with questionable dementia. The educational level in the original study was higher, being 10.4 years for controls and 9.5 years for subjects with dementia. Despite this, the sensitivity, specificity and AUC for the comprehensive scoring systems were significantly higher in our study. Optimal cut-off scores were also higher for the AMT, CMMSE and CDT by all scoring methods compared with the original cut-off scores. Therefore, it is likely that above and beyond the effect of education, it is the early stage of dementia in our study population that resulted in the higher optimal cut-off scores.

Nonetheless, our results do support the mediation of educational attainment on optimal cut-

off scores. There was a difference in cut-off scores for the comprehensive scoring protocols between educational groups, although educational level did not appear to influence optimal cut-off scores in abbreviated scoring methods. In subjects with early dementia with >6 years of education, mean scores were actually better than the original cut-off scores for the comprehensive clock drawing, Watson and Schulman methods. In other words, a significant proportion of higher-educated subjects with early dementia would have been classified as 'normal' if the original cut-off scores were used. Notably, even in subjects with ≤6 years of education, optimal cut-off scores were still higher than the original cut-offs for all scoring methods except Lin's simplified 3-item method. Therefore there is a need to adjust cut-off scores for both early stage of dementia and educational level. This is particularly pertinent in Asia, where there is a large variation in the levels of education among older people. Our findings are supported by a previous Asian study which compared subjects with early dementia to age-matched controls and found markedly different CDT optimal cut-off scores for people with <2 years, 2-6 years and >6 years of education.[8]

The superior diagnostic performance of the CDT by all scoring methods in subjects with ≤6 years of education supports the use of the CDT as a screening tool even in subjects with minimal education. Our findings are consistent with previous studies,[6,8] which reported higher sensitivity for the CDT in subjects of lower education, albeit with lower specificity. For cognitive screening purposes though, it could be argued that higher sensitivity would be preferable to high specificity to maximise detection of early dementia.

Overall, the CDT is an easy assessment tool well accepted by our elderly subjects with educational levels varying between 0 to 14 years. By use of a pre-drawn circle, any potential errors caused by a small freely drawn clock may be minimised, because illiterate subjects with no formal education may find the task of holding a pen to draw a clock face difficult. It takes less than one minute to score the comprehensive scoring system, and the entire CDT can be completed in less than 2 minutes. Combined with the good diagnostic utility shown, these factors support the potential role of the CDT using a pre-drawn circle as an efficient screening tool for dementia in the outpatient setting.

Our study had several limitations. First, the small sample size did not allow further analysis according to aetiology of dementia. Our assessment was also limited to 5 particular CDT methods only. Each CDT method was rated by a single rater; therefore inter-rater reliability was not determined. This would have been particularly pertinent for the Schulman method, in which the hierarchical scoring scale requires more subjective judgment. Our study sample was derived from a select population of patients with memory complaints attending a tertiary referral Memory Clinic, and the vast majority was ethnically Chinese. This may limit the generalisability of our findings to other ethnic groups and other settings.

CONCLUSION

The CDT using a pre-drawn circle has good diagnostic utility for detecting persons with early dementia, with comprehensive scoring systems outperforming abbreviated methods. Higher cut-off scores are required compared to quoted cut-off scores for all methods in view of the early stage of disease. Educational level appears to influence optimal cut-off scores in comprehensive but not abbreviated CDT methods. Larger studies are needed to confirm the findings of our preliminary study that the CDT is a valid and useful cognitive screening tool when appropriate education-adjusted cut-off scores are used, particularly in subjects with low levels of education.

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