THE CLOCK DRAWING TEST FOR DEMENTIA OF THE ALZHEIMER’S TYPE: A COMPARISON OF THREE SCORING METHODS IN A MEMORY DISORDERS CLINIC

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ABSTRACT

Objectives. To examine the reliability and validity of the Clock Drawing Test when used as a cognitive screening instrument for mild to moderate dementia, and to compare different scoring mechanisms.


Setting. Hospital-based memory disorders clinic.

Participants. A sample of 28 consecutive patients attending the memory clinic for assessment who were given a diagnosis of Alzheimer’s disease (mild or moderate) and 28 age- and sex-matched control subjects comprising 17 memory clinic attenders found to be normal and 11 community volunteers.

Measurements. Sensitivity and specificity of the three clock rating scales against memory clinic diagnoses of dementia using DSM-III-R; their respective interrater reliabilities; and comparisons of each with measures of cognitive impairment (the Mini-Mental State Examination and the Blessed Orientation–Information–Memory–Concentration Test), daily performance of basic and instrumental activities (the Blessed Dementia Scale) and depression (the Hamilton Rating Scale for Depression).

Results. All methods of scoring the Clock Drawing Test correlated well with measures of cognitive impairment ($r = 0.57–0.73$) and daily performance ($r = 0.38–0.48$), were independent of mild depression and demonstrated high sensitivity, specificity and interrater reliability. While all clock scales identified mild to moderate dementia reasonably well, the Shulman method performed best. In screening for dementia, clock drawing proved superior to the MMSE: 24/28 vs 20/28 cases identified. When compared with the MMSE, clock drawing provided additional diagnostic discrimination, identifying 7/8 AD patients with MMSE scores $\geq 24$.

Conclusions. In a clinic population, clock drawing, especially if scored according to the Shulman scale and combined with the MMSE, is an extremely efficient test screening measure for mild to moderate dementia of the Alzheimer's type with low false negative and false positive rates. This may have implications for screening elderly populations. © 1997 by John Wiley & Sons, Ltd.

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KEY WORDS—Alzheimer’s disease; screening; dementia; clock drawing; reliability

A useful test which is known to reflect frontal and temperoparietal functioning is the easily remembered and quickly administered Clock Drawing Test (Critchley, 1953). The individual is asked to draw the face of a clock, mark in the hours and then draw the hands to indicate a specified time (for example, 10 past 10). Clock drawing correlates well with other more detailed and time-consuming cognitive screens, and has the advantage of being non-threatening (Shulman et al., 1986). The effects of education remain controversial, with some researchers questioning the validity of clock...
drawing in lowly educated subjects (Ainslie and Murden, 1993).

The utility of the clock test has been enhanced by the recent development of a number of scales for scoring (Table 1). Shulman et al. (1986) found that their scale of error classification for clock drawings proved to be acceptably sensitive and specific to cognitive impairment, and was later improved by including intact clocks (ie no errors) (Shulman et al., 1993). Sunderland et al. (1989) found non-significant differences between clinicians’ and non-clinicians’ ratings of clock drawings, and significant correlations with measures of dementia severity. Wolf-Klein et al (1989) concluded that the test could be used as a low-cost screening tool for cognitive impairment associated with AD.

These three clock drawing tests are different. In the modified Shulman method (Shulman et al., 1993), subjects are asked to add the numbers of a clock face to a predrawn circle and to mark in the hands at 10 after 11. Scores are as follows: 1 ‘a perfect clock’; 2 ‘mild visuospatial errors’; 3 ‘errors in denoting the specified time’; 4 ‘moderate visuospatial disorganisation’; 5 ‘severe visuospatial disorganisation’; and 6 ‘no reasonable representation of a clock’.

The Sunderland method requires subjects to draw, on a blank sheet of paper, ‘a clock with all the numbers on it’, and then to put the hands on the clock to ‘make it read 2:45’. There are 10 scoring points. Sample anchor points include: 10 ‘hands are in correct position’; 7 ‘placement of hands is significantly off course’; 4 ‘further distortion of number sequence’; and 1 ‘either no attempt or an uninterpretable attempt is made’.

In the Wolf-Klein method, subjects are merely asked to ‘draw a clock’ on a preprinted circle. Their scoring system has 10 anchor points which pertain only to the spacing of the numbers; time setting is not assessed. Sample anchor points include: 10 ‘normal’; 7 ‘very inappropriate spacing’; 4 ‘counterclockwise rotation’; and 1 ‘irrelevant figures’.

Our aim was to evaluate these multiple scales and scoring methods in a memory disorders clinic setting in relation to (i) interrater reliability and (ii) diagnostic accuracy with respect to the sensitivity and specificity against categorical diagnosis, using DSM-III-R (American Psychiatric Association, 1987) criteria, and dimensional measures of general cognitive function, activities of daily living and instrumental activities of daily living. Further aims of the study were to evaluate (iii) the relationship between the Clock Drawing Test and more commonly used cognitive screens for dementia and (iv) whether clock drawing adds additional diagnostic information to routine cognitive screening with the Mini-Mental State Examination (MMSE; Folstein et al., 1975).

METHOD

Data were analysed for consecutive referrals to a memory disorders clinic between 1990 and 1993 for patients who were aged over 50 years, for whom sufficient data were available for analysis and who met standard criteria for mild to moderate dementia and Alzheimer’s disease (see below). Patients with severe dementia almost invariably draw clocks poorly or not at all. Their exclusion conservatively biased our evaluation of the tests. Two patients with a Hamilton Rating Scale for Depression (HRSD) (Hamilton, 1960) score of 16 or above were excluded from the study, as were patients with receptive aphasias, visual impairment, vascular dementia and other dementias. No patient had motor impairment that prevented clock drawing.

Memory clinic patients and their informants were assessed by a psychiatric registrar and also, if indicated, by a psychogeriatrician, a neuropsychiatrist and/or a neurologist. Additionally, patients were assessed by a neuropsychologist and informants by a social worker. Where indicated, an occupational therapist assessed the patient at home. The drawing of a clock was a standard component of the psychiatric assessment. All patients were given a blank sheet of paper, asked to draw a circle, fill in the hours of a clock and then mark in the hands for 10 minutes past 10. None of the clocks produced by the subjects was incorrect because of a faulty circle. All clocks were scored independently by two psychologists using the three methods. Raters for this study were blind to the subjects’ diagnoses, severity and MMSE scores.

Information derived from clinical assessment, laboratory investigations, electroencephalography and neuroimaging were reviewed at a case conference (Brodaty, 1990), where a consensus diagnosis was made using DSM-III-R (American Psychiatric Association, 1987) and NINCDS–ADRDA (McKhann et al., 1984) criteria. Scales relevant to this study comprised those of the MMSE (Folstein et al., 1975), the Blessed Orientation–Information–Memory–Concentration Test (OIMC) and Dementia Scales (DS) (Blessed et al., 1968), as well as the HRSD. Not all the recruited...
Table 1. Summary of scoring mechanisms developed for the Clock Drawing Test

<table>
<thead>
<tr>
<th>Researchers</th>
<th>Scale type</th>
<th>Test sample</th>
<th>Criterion standard</th>
<th>Interrater reliability</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shulman Shedletsky &amp; Silver (1986); Shulman, Gold, Cohen &amp; Zuccherò (1993)</td>
<td>6-point hierarchical error classification scale producing a global rating of impairment and including normal clocks (1 = 'perfect', 6 = 'no reasonable representation of a clock')</td>
<td>$N = 75$ (37 males, 38 females), aged 65+ (mean age 75.5 years). Sample comprised approximately equal groups of organic mental disorder, major affective disorder and normal controls</td>
<td>MMSE used as a measure of cognitive impairment score $\leq 23 =$ cognitively impaired ($N = 21$), score $&gt; 23 =$ normal ($N = 54$). Score on the Clock Drawing Test of $\geq 3 =$ cognitively impaired, score of 1 or 2 = normal</td>
<td>0.75</td>
<td>0.86</td>
<td>0.72</td>
</tr>
<tr>
<td>Sunderland, Hill, Mellow, Lawlor, Gundersheimer, Newhouse &amp; Grafman (1989)</td>
<td>10-point anchored scale (1 = 'either no attempt or uninterpretable attempt', 10 = 'hands are in correct position')</td>
<td>$N = 150$; 67 Alzheimer's patients (mean age = 67.7 $\pm$ 9.7), 83 normal controls (mean age = 73 $\pm$ 7.9)</td>
<td>AD according to DSM-III-R and NINCDS–ADRDA criteria. Clock score $\geq 6 =$ normal, score $&lt; 6 =$ cognitive impairment</td>
<td>0.86</td>
<td>0.78</td>
<td>0.96</td>
</tr>
<tr>
<td>Wolf-Klein, Silverstone, Levy, Brod and Breuer (1989)</td>
<td>10-point categorical scale based on 10 clinically derived categories (1 = 'irrelevant figures', 10 = 'normal')</td>
<td>$N = 312$ consecutive admissions (mean age = 76.8, range 58–99). Sample included: 130 normals, 106 AD, 26 MID, 15 AD + MID, 35 other (mostly depression)</td>
<td>Differential diagnosis of dementing diseases using NINCDS–ADRDA criteria. Categories 1–6 = cognitive impairment categories 7, 9, 10 = normal. Category 8 was excluded as it had an indeterminate relationship to mental categories</td>
<td>Not done</td>
<td>For all subjects, excluding category 8, 0.68</td>
<td>0.98</td>
</tr>
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</table>

normal controls received the OIMC, DS or the HRSD (see Table 2). Data were analysed using intraclass correlation (ICC) (Bartko and Carpenter, 1976), Pearson’s product moment correlation, the chi-square test and Student’s $t$ tests.

RESULTS

The sample

The patient group consisted of 28 subjects aged 50 or more who had received a diagnosis of Alzheimer’s disease (AD), and the controls comprised 17 memory clinic referrals with memory complaints who were found to be normal and 11 normal older subjects with no memory recruited for another research project within the department (see Table 2). The two subgroups of control subjects were found not to differ significantly on age, years of education, scores obtained on the MMSE, OIMC, HRSD or the DS, or in clock drawing performance on the three scales.

Clock drawing: sex, age and education

Male and female subjects were similar as regards diagnoses, level of cognitive impairment or clock drawing ability. Although the AD and normal control groups were of similar age ($t = 1.64, df = 54$, non-significant), analyses were performed to examine the possible effect of age on clock drawing performance. Age of the whole sample (AD and normal controls) was found to correlate significantly with clock drawings scored by the Shulman ($r = 0.39, p < 0.01$), Sunderland ($r = -3.35, p < 0.01$) and Wolf-Klein ($r = -0.29, p < 0.05$) scales. When the AD patients were examined separately, age was found not to correlate significantly with any of the three clock scales (Shulman, $r = 0.35$; Sunderland, $r = -0.35$; Wolf-Klein, $r = -0.29$, all non-significant). When the normal control subjects were examined separately, a significant correlation was found only between the Shulman scale and age ($r = 0.41, p < 0.05$), although even this did not remain significant when adjustments for multiple comparisons were made.

Control subjects were significantly more educated than AD subjects ($t = -2.65, p < 0.01$). Correlations between years of education and clock drawing performance were significant for both the Shulman ($r = -0.35, p < 0.01$) and the Sunderland scale ($r = 0.32, p < 0.05$), but not the Wolf-Klein scale ($r = 0.20$). The possible confound that our normal controls were more highly educated ($F = 3.51, p < 0.05$) was examined by analysis of covariance for each of the three scales. The AD subjects continued to perform significantly worse than the control subjects on each of the clock rating scales even when the effects of education were partialled out.

Comparison of the three clock rating scales

The interrater reliabilities of each of the three scales as measured by the intraclass correlation coefficient (ICC; Ritchie and Fuhrer, 1992) were all fairly similar and relatively high (Table 3). The second aim of the study was to compare the relative sensitivities and specificities of the three scales with respect to clinical diagnosis. The 1993 revised Shulman scale advocated that a score of <= 2 out of a possible 6 indicated normality, and a score of > 2 indicated cognitive impairment.

<table>
<thead>
<tr>
<th>Table 2. Description of the sample</th>
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<tr>
<td>$N$</td>
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<tr>
<td>Age (years)</td>
</tr>
<tr>
<td>Mean (SD) 73.1 (8.9)</td>
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<tr>
<td>(range) 50–59</td>
</tr>
<tr>
<td>Percentage male 32.1%</td>
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<tr>
<td>Years of education</td>
</tr>
<tr>
<td>Mean (SD) 8.7 (2.6)</td>
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<tr>
<td>(range) 6–15</td>
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<tr>
<td>Severity of dementia (DSM-III-R categories)</td>
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<tr>
<td>Mild 14</td>
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<tr>
<td>Moderate 14</td>
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<tr>
<td>MMSE</td>
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<tr>
<td>Mean (SD) 19.5 (5.3)</td>
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<tr>
<td>(range) 8–29</td>
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<tr>
<td>OIMC</td>
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<tr>
<td>Mean (SD) 23.5 (8.2)</td>
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<tr>
<td>(range) 5–36</td>
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<tr>
<td>Dementia Scale</td>
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<tr>
<td>Mean (SD) 4.5 (2.9)</td>
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<tr>
<td>(range) 0.5–12.5</td>
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<tr>
<td>Hamilton</td>
</tr>
<tr>
<td>Mean (SD) 5.3 (4.5)</td>
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<td>(range) 0–14</td>
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</table>
Our results support the use of the 2/3 cut as representing the best trade-off between sensitivity (0.86) and specificity (0.96). The 5/6 cut-point proposed by Sunderland et al. for use in their clock rating scale produced a sensitivity of 0.57 and a specificity of 1.0. Cut-points of 6/7 and 7/8 resulted in sensitivities of 0.61 and 0.64 and specificities of 0.96 and 0.93 respectively. The best result was achieved using an 8/9 cut: 0.79 sensitivity and 0.93 specificity.

Assuming that higher scores on the Wolf-Klein scale represent better performance, the recommended cut-point of 6/7 achieved a sensitivity of 0.36 and a specificity of 1.0. The best result was achieved with an 8/9 cut: 0.79 sensitivity and 0.89 specificity. When we repeated the analyses of the Wolf-Klein scale, excluding category 8 (‘mild spacing abnormalities’), as recommended by Wolf-Klein et al. (1989), the results were inferior. As there were many category 8 scorers in our sample and exclusion did not improve performance, we used the full Wolf-Klein scale with an 8/9 cut for further analyses.

Receiver operating characteristic (ROC) curve analysis (Murphy et al., 1987; Ritchie and Fuhrer, 1992) demonstrating that the Shulman scale had the highest discriminatory power, followed by the Sunderland scale and lastly the Wolf-Klein scale (Fig. 1).

Table 3. Correlation between clock rating scales and other memory clinic measures and assessment of interrater reliability

<table>
<thead>
<tr>
<th>Clock rating scale</th>
<th>MMSE</th>
<th>OIMC</th>
<th>Dementia scale (DS)</th>
<th>Hamilton (HRSD)</th>
<th>Rater 1 vs rater 2 (ICC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shulman et al. (1993)</td>
<td>-0.618*</td>
<td>-0.573*</td>
<td>0.483**</td>
<td>0.062</td>
<td>0.891*</td>
</tr>
<tr>
<td>Sunderland et al. (1986)</td>
<td>0.725**</td>
<td>0.624**</td>
<td>-0.434*</td>
<td>0.010</td>
<td>0.924*</td>
</tr>
<tr>
<td>Wolf-Klein et al. (1989)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Including category 8</td>
<td>0.580***</td>
<td>0.578***</td>
<td>-0.381*</td>
<td>0.164</td>
<td>0.875*</td>
</tr>
<tr>
<td>Excluding category 8</td>
<td>0.620***</td>
<td>0.631**</td>
<td>-0.446*</td>
<td>0.203</td>
<td>N/A</td>
</tr>
</tbody>
</table>

*p < 0.01; **p < 0.001; ***p < 0.0001; significance calculated by F test.

Fig. 1. Receiver operating characteristic curves for the Shulman, Sunderland and Wolf-Klein scales
Clock drawing as a measure of cognitive impairment

The third issue addressed was the relationship between the various clock rating scales and other measures of cognitive impairment. Table 3 shows the rank order correlations between each of the three clock rating scales and other memory clinic assessment measures. Both the MMSE and the OIMC were found to be highly significantly and the DS significantly related to all of the three clock rating scales with minimal differences between them. Not surprisingly, since patients with significant depression were excluded from the study, the HRSD did not correlate significantly with any of the three clock rating scales.

Clock drawing: additional diagnostic information?

Twenty of the 28 patients with a diagnosis of dementia obtained MMSE scores <24. In contrast, the Clock Drawing Test alone identified 24 of the 28 dementia patients. Of the eight AD patients with MMSE scores ≥24, the numbers correctly identified by the different scales were: seven on the Shulman scale (2/3 cut); three or five on the Sunderland scale (5/6 or 8/9 cuts respectively); and one or seven on the Wolf-Klein scale (6/7 or 8/9 cuts). Of the 20 AD patients with MMSE scores <24, the Shulman 2/3 cut failed to identify three (false negative rate FNR = 15%), the Sunderland 8/9 cut missed three (FNR = 15%) and the Wolf-Klein 8/9 cut missed five (FNR = 25%).

Clock drawing as a screening instrument

At the optimal cut-points identified in the current article, there are two choices for determining the effectiveness of clock drawing in combination with the MMSE as a cognitive screen in a memory clinic population. First, persons can be regarded as cognitively impaired (and at a risk of dementia) if they fail both the MMSE and the Clock Drawing Test. This resulted in sensitivities and specificities of 0.40 and 1.0 for the Shulman, 0.50 and 1.0 for the Sunderland and 0.36 and 1.0 for the Wolf-Klein scale. Secondly, they can be identified by failure on either the MMSE or the Clock Drawing Test. Sensitivities and specificities for this procedure were 0.96 and 0.96 for the Shulman, 0.86 and 0.96 for the Sunderland and 0.86 and 1.0 for the Wolf-Klein scale.

Benign senescent forgetfulness

As an aside, we were curious whether the controversial diagnosis of benign senescent forgetfulness (BSF; Kral, 1962) could be distinguished from early dementia by clock drawing. Seven memory clinic patients were diagnosed at index assessment and confirmed at follow-up 1–2 years later to have stable non-progressive memory impairment without development of other cognitive deficits. These patients were compared with only the mild AD patients (N = 14) using all three clock scales. The BSF patients did not differ significantly from the AD group in terms of their education, age, gender distribution or Hamilton score. Using the suggested 2/3 cut-point, the Shulman scale correctly identified five out of seven of the BSF subjects as normal and 12 out of 14 of the mild AD as impaired, yielding a sensitivity of 0.71 and a specificity of 0.86. The 8/9 cut on the Sunderland resulted in both a sensitivity and specificity of 0.86. Using the 8/9 cut on the Wolf-Klein, the sensitivity was 0.57 and the specificity 0.79.

DISCUSSION

While various clock tasks and scoring methods have demonstrated validity as cognitive screens, none has hitherto been identified as superior (Varner et al., 1995). This is the first article to compare three of the most commonly used and cited scoring systems, the Shulman, Sunderland and Wolf-Klein scales.

Whichever scoring system was used, the Clock Drawing Test was found to be effective in identifying mild to moderate dementia in a memory disorders clinic population and to correlate highly significantly with two commonly used measures of cognitive ability and a measure combining basic and instrumental activities of daily living (the Blessed Dementia Scale). Additionally, clock drawing performance was found to be independent of depressive symptoms as measured by the Hamilton Rating Scale for Depression. This replicated the findings of Shulman et al. (1986), who found depression, as measured by the Geriatric Depression Rating Scale, to be independent of clock drawing performance. Further, differences in education between our two groups did not appear to affect the Clock Drawing Test’s discriminatory ability.

All three scales had similarly high interrater reliabilities. However, in this clinic population...
there were differences in their sensitivities and specificities. The Shulman scale performed best in terms of (i) replication of the authors’ suggested cut-points, (ii) higher sensitivity and specificity values, and (iii) ROC analysis. To obtain acceptable sensitivities and specificities with the Sunderland and Wolf-Klein scales, the published cut-points had to be significantly altered, probably reflecting sampling differences. Cut-points are likely to differ when instruments are evaluated in populations with lower prevalence rates of dementia. Also, our study placed more demandings on the tests in that patients with severe dementia, who are reasonably easy to identify, were excluded.

Our study supported the argument by Tuokko et al. (1992) that spacing errors may be a particularly sensitive discriminator between normal and abnormal cognitive performance. Given the very high frequency of category 8 scores using the Wolf-Klein method in those with mild to moderate AD, the relationship between cognitive impairment and mild spacing errors may not be as indeterminate as Wolf-Klein et al. suggested and argues against their recommendation to eliminate category 8 (‘almost normal except for spacing’) from scoring. Whether category 8 is included or not, the ROC curve demonstrates that the Wolf-Klein scale is not as impressive as the other two scales examined in discriminating AD from normality. This may in part result from its omission of potentially vital information by not examining time-setting ability, as the hands are not scored. Time-setting appears to enhance test sensitivity.

The limitations of the MMSE, the most commonly used screening instrument for dementia, are well known (Tombaugh and McIntyre, 1992). In particular, its ceiling characteristics mean that early dementia can be easily missed. Our results, albeit in a clinic population, indicate that 87.5% of those patients with a clinical diagnosis of AD, who performed within the normal range on the MMSE, would be correctly identified by the Shulman scale as being cognitively impaired. This is superior to the Sunderland scale (62.5%), and vastly superior to the Wolf-Klein scale (14.3%). Of those subjects detected by the MMSE and clinically diagnosed as having dementia, but performing normally on the Clock Drawing Test, the Shulman and Sunderland scales had equal and significantly lower false negative rates than the Wolf-Klein scale.

When used in combination with the MMSE, the Clock Drawing Test provided additional diagnostic information. This might be expected, as frontal and temporoparietal functions (both measured by clock drawing) are not well assessed by the MMSE, despite these functions being commonly affected in AD. In the current study, not only did the addition of clock drawing to the MMSE result in a higher true positive rate for dementia, using DSM-III-R (American Psychiatric Association, 1987) criteria and consensus diagnosis as the gold standard, but the addition of the MMSE to clock drawing also reduced false negative rates. This suggests that the combination of MMSE and the Clock Drawing Test may provide a more powerful screen for cognitive impairment. The performance of such a combination in an elderly general population sample would need to be tested, as lower prevalence rates of dementia significantly alter the properties of any screening instrument (Weinstein and Fineberg, 1980; Ritchie and Fuhrer, 1992).

Practically, the Shulman scale has, in addition to the points discussed above, the additional advantage of being only six points (as opposed to 10 with the Sunderland and Wolf-Klein scales), making it simpler to score. The slightly more complicated Sunderland scale has been criticized for assuming that ‘the representation of the hands is first and solely affected (score 6 to 10), and additional errors in the representation of numbers and the clock face occur later (score 1 to 5),’ (Rouleau et al., 1992). A potential advantage of the Sunderland scale is in relation to BSF patients, where its ability to discriminate between the mild AD and BSF patients was marginally superior to that of the Shulman scale.

We suggest that the limitations to our study—sample size, lack of poorly educated subjects, lack of rural subjects and use of a clinic population—are balanced by our rigorous subject selection criteria, exclusion of severe cases of dementia and those with aphasia, careful diagnostic assessment, use of categorical as well as multiple dimensional outcome criteria, choice of clinically relevant normal controls and follow-up of borderline cases. Longitudinal study of a population at high risk of developing dementia using a battery of screening instruments, including serial MMSEs and Clock Drawing Tests, would be helpful in confirming the utility of these tests and their cut-points. Differences in optimal cut-points on clock scores from published reports may reflect sampling differences or the more rigorous selection of comparative groups here. In a clinical setting where detailed neuropsychological testing will be performed to
investigate suspected cognitive deficits, it may be preferable to use a lower threshold since clock drawing may be more useful as a cognitive screen with higher sensitivity, at the expense of specificity. Despite only testing seven cases of BSF, the ability of the Clock Drawing Test to discriminate between BSF and AD was impressive.

CONCLUSION

The Clock Drawing Test proved useful in testing older populations attending a memory disorders clinic for assessment of dementia. It requires minimal equipment, is portable, is quick and can be administered to the hearing impaired (with written instructions if necessary), the very ill and the poorly educated (Death et al., 1993). We have found the Shulman method of scoring easy to follow and reliable. Clock drawing might prove especially helpful for screening for significant cognitive impairment in general practice and hospital settings (Huntzinger et al., 1992), especially in combination with the MMSE.

ACKNOWLEDGEMENTS

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