Sensitivity and Specificity of Cognitive and Functional Screening Instruments for Dementia: The Indo-U.S. Dementia Epidemiology Study

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There is a shortage of adequate screening instruments for dementia in poorly educated populations and non–English-speaking groups. An epidemiological survey was conducted in a population-based, largely illiterate, sample of 5,126 individuals aged 55 and older in 28 villages in the rural community of Ballabgarh in northern India. All participants were administered a general mental status test, the Hindi Mental State Examination (HMSE), and a brief battery of neuropsychological tests. Their informants answered a questionnaire assessing functional ability, the Everyday Abilities Scale for India (EASI). Six hundred thirty-two participants underwent clinical diagnostic evaluation for dementia. We investigated whether the sensitivity, specificity, and predictive value for dementia of the mental status test could be improved by the addition of the brief neuropsychological test battery or the functional questionnaire, comparing the instruments alone and in combination. In participants who could be tested cognitively, the HMSE, the neuropsychological battery, and EASI had sensitivities of 81.3%, 81.3%, and 62.5%, respectively, with specificities of 60.2%, 74.5%, and 89.7%, respectively. The combination of all three was 93.8% sensitive and 41.8% specific. The sensitivity of the HMSE alone was nonsignificantly improved by the addition of either the EASI or the neuropsychological battery, whereas its specificity was significantly decreased by either addition. An advantage of the EASI was that it could also be administered to informants of subjects who were cognitively untestable. In this largely illiterate community, with a low prevalence of dementia, the combination of cognitive tests and a functional ability questionnaire had substantial value for population screening. **J Am Geriatr Soc 50:554–561, 2002.**

Key words: aging; epidemiology; community study; population study; predictive value; mental status

As interventions for Alzheimer's disease (AD) become available, it will become increasingly useful to detect early dementia in the population at large. Dementia, including AD, increases dramatically in incidence with age and is recognized as a major public health problem in the United States and other industrialized countries. However, it may become an even more significant problem in developing countries, where it is estimated that more than 70% of the world's 1 billion people aged 60 and older will be located by the year 2020.[1] By that time, in India alone, there will be 132 million adults aged 60 and older.[1] Research on dementia and other chronic diseases in developing countries has lagged behind similar research in the industrialized nations and also behind other health research (e.g., on infectious diseases) in developing countries themselves. Reasons are multiple and complex but include overall limitations of resources, lower priorities for research on older adults, and lack of appropriate assessment tools. With respect to dementia, there has been a lack of adequate screening instruments for the rapid identification of potentially demented individuals, particularly in populations that are poorly educated and vastly diverse in language and culture. Such instruments would also be of value in the assessment of poorly educated patients and research subjects anywhere.

As part of a collaborative Indo-U.S. cross-national epidemiological study of dementia, we developed a set of instruments to screen for dementia in the largely illiterate,

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Supported in part by Grants #AG07562 and #AG09202 from the National Institute on Aging, National Institutes of Health, United States Department of Health and Human Services.

Presented in part as a poster at the 14th Annual Meeting of the American Association of Geriatric Psychiatry, San Francisco, CA, February 23–26, 2001.

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0002-8614/02/$15.00

Hindi-speaking, rural older population of Ballabgarh in Northern India. These tools included a general mental status test, a brief battery of neuropsychological tests utilizing a range of cognitive domains, and a newly developed informant questionnaire on functional ability. We have previously reported descriptions of and norms for these instruments.[2–4] In this article, we report and compare their sensitivity, specificity, and predictive value for dementia within our study cohort.

Typically, dementia screening is performed by means of a brief mental status test such as the Mini-Mental State Examination (MMSE).[5] Standard diagnostic criteria for AD and other dementia[6] require impairment to be present in two or more cognitive domains and accompanied by difficulty with social and occupational functioning. We therefore set out to determine whether the sensitivity and specificity of a general mental status test could be improved by supplementing it with a brief battery of cognitive tests, and with a measure of functional disability.

METHODS

Background

The Indo-U.S. Cross National Dementia Epidemiology Study, a collaborative project between the Center for Ageing Research in India and the University of Pittsburgh, was funded by the National Institute on Aging (National Institutes of Health, U.S. Department of Health and Human Services) from 1991 to 1999. A major component was the development of suitable instruments for screening and diagnosing the Indian study population. Instrument development for dementia screening was a particular challenge because the Indian study population was Hindi-speaking and largely illiterate and because the instruments had to be sufficiently similar to those already in use in the ongoing study in the U.S. study cohort to allow judicious cross-national comparisons to be made.[7–10]

Study Populations

The Indian sample consisted of 5,126 individuals, out of a total population of 5,134 persons aged 55 and older, in the rural community of 28 villages in the Ballabgarh district of the state of Haryana in northern India. The Comprehensive Rural Health Services Project (CRHSP) of the Center for Community Medicine of the All India Institute of Medical Sciences serves this community, which is approximately 35 kilometers from New Delhi. The CRHSP maintains an up-to-date census database to which we were given access. Details of sampling and recruitment of the Indian cohort have been described previously.[11]

The reference U.S. study population consisted of a cohort drawn from the rural community of the mid-Monongahela Valley near Pittsburgh, in southwestern Pennsylvania. This cohort has participated since 1987 in an ongoing prospective community study of the epidemiology of dementia, known as the Monongahela Valley Independent Elders Survey (MoVIES Project). Details of the reference U.S. study population have been described previously.[7,8] The MoVIES cognitive screening battery incorporated the Consortium to Establish a Registry for Alzheimer's Disease (CERAD) neuropsychological test panel,[12] which included the MMSE;[5] the 10- item CERAD Word List for Learning, Delayed Recall, and Delayed Recognition;[12,13] the 15-item CERAD version of the Boston Naming Test;[14] and a four-item Constructional Praxis task, among others. The above tests were translated and adapted for the Ballabgarh study, resulting in the standardized Hindi screening battery described below.[2,3]

Cognitive Screening

The process of developing the cognitive and functional screening instruments took 3 years and multiple iterations of pretesting, pilot testing, and field testing, which have been described previously.[2–4] During the subsequent prevalence survey, trained interviewers administered the Hindi cognitive screening battery, which consisted of the following tests.

1. Hindi Mental State Examination (HMSE),[2] a Hindi adaptation of the MMSE.[5] In brief, the major adaptions were in (1) orientation to the year, a piece of information which was not common knowledge among these older, illiterate, rural persons and for which we substituted time of day; (2) the attention subtest requiring abstract serial subtractions, for which we substituted a word problem involving cash transactions and requiring serial subtractions; (3) the attention subtest requiring backwards spelling of the word WORLD, for which we substituted the task of naming the days of the week backwards; (4) the written sentence generation subtest for which we substituted the oral task "tell me something about your house"; and (5) the constructional praxis task (copying) task, in which a simpler diagram of a diamond within a square replaced the more-complex intersecting pentagons of the MMSE.
2. Word List—Immediate Recall, Delayed Recall and Delayed Recognition of a 10-item Word List, using auditory rather than visual presentation of words for our largely illiterate cohort.[3,12,13]
3. Verbal Fluency for words in the categories of fruits and animals.[3,12,15]
4. Object Naming Test — a confronting naming test requiring subjects to name three-dimensional objects (models),[3] rather than line drawings as in the prototype Boston Naming Test.[15]
5. Constructional Praxis — copying line drawings of a circle, a diamond, intersecting rectangles, and a cube.[3,12,16]

Criteria for Cognitive Impairment

On the HMSE and all tests in the cognitive battery, a lower score reflects greater impairment. Operational criteria for "cognitive impairment" were based on percentiles of the study sample itself. Subjects were classified as cognitively impaired if they scored at or below the 10th percentile of the sample on the general mental status test (HMSE) or of the sample on the memory test (Word List Immediate

Recall or Delayed Recall) and on at least one other test. This percentile-based and multiple domain–based approach to classifying subjects as cognitively impaired was shown to be more sensitive and specific for dementia than the use of a general mental status test (MMSE) alone in the reference U.S. study population.[8] It should be noted here that the percentile-based screening criteria were used only to select individuals for more-detailed clinical evaluation and not to diagnose dementia; the diagnostic evaluation was conducted independently of the screening data.

Functional Ability Scale — Everyday Abilities Scale for India

A new functional ability scale, in the form of an informant questionnaire, was developed to assist in dementia screening of this largely illiterate, rural, older Indian cohort. Development of the Everyday Abilities Scale for India (EASI) has been described in detail previously.[4] In brief, we first selected by discussion and consensus a lengthy list of items representing the regular tasks that older adults were expected to perform in rural Ballabgarh society, bearing in mind the traditional Western concepts of activities of daily living (ADLs)/instrumental activities of daily living (IADLs) assessment and the local culture and level of technological advancement. Through an iterative process of pretesting, pilot testing, and field testing, we improved its reliability and internal consistency, eliminating items that were too rarely endorsed or too strongly intercorrelated and therefore redundant. As a final validation of the capacity of the EASI to detect functional impairments relevant to dementia, we examined the correlations of EASI scores with HMSE scores in the field-test sample. In its final form, this scale consisted of an 11-item questionnaire that addressed personal care, mobility, social interaction, and cognitive functioning. The items included the following abilities: to remember that one has just eaten and not immediately ask for food again, to use the toilet area appropriately, to keep clothing from becoming soiled with excreta, to button the upper garment appropriately, to wrap or tie the lower garment appropriately, to participate appropriately in group/team activities, to express opinions on important family matters, to follow tasks through to completion, to remember important local holidays and festivals, to remember to deliver messages, and to discuss local/regional events and issues appropriately. A questionnaire addressing these items was administered to a reliable household member, who was asked whether or not the subject had difficulty in performing the activities listed.

Criteria for Functional Disability

On this 11-item scale, a point is scored for each item in which a disability is reported, thus a higher score reflects greater impairment. Informants reported no disability (score of 0) in 71.4% of subjects; 15.3%, 9.1%, and 4.2% of the cohort scored 1, 2, and 3 or more, respectively. For the present study, subjects were classified as "functionally disabled" based on inability to perform three or more of the items on the EASI. All "cognitively impaired" and "functionally disabled" subjects, as defined above, and a 5% random sample of unimpaired "control" subjects were selected for clinical and diagnostic evaluation.

Clinical Evaluation and Diagnosis of Dementia

A standardized clinical diagnostic protocol[17] was used to establish the presence or absence of a dementia and, if present, its stage of severity, likely cause, and estimated date of onset. The clinical evaluators were the project medical officer and neurologist who were blind to the screening data that were used to select subjects for clinical evaluation. The evaluation included a detailed history and general physical, neurological, and mental status examination of the subject and a further interview with a reliable informant. If a subject had died between screening and clinical evaluation, family members were interviewed to determine whether the subject met criteria for dementia before death. All available information was used in making the diagnosis of dementia according to the *Diagnostic and Statistical Manual of Mental Disorders, Third Edition, Revised* (DSM-III-R) criteria.[6] The stage of dementia was rated using the Clinical Dementia Rating (CDR) scale.[18]

Informed consent was obtained for all study procedures, as approved by the University of Pittsburgh Institutional Review Board and the Human Volunteers Protection Committee of the Centre for Ageing Research in India.

Statistical Methods

Data were analyzed using statistical software (SAS, version 6.12, SAS Institute, Inc., Cary, NC) except for receiver operating characteristic (ROC) curves, which were obtained using the statistical software STATA, version 6.0 (STATA Corporation, College Station, TX). Descriptive statistics were calculated for basic demographic variables. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of each screening tool and combination of tools were calculated against a DSM-III-R diagnosis of dementia with a CDR score of 0.5 or higher. For these calculations, "screening positive" indicates being classified as impaired by the relevant criteria described above. True positives (TP) were those who screened positive and were diagnosed as demented, false positives (FP) were those who screened positive but were not demented, true negatives (TN) were those who screened negative and were not diagnosed as demented, and false negatives (FN) were those who screened negative but were diagnosed as demented. Sensitivity was calculated as TP/TP + FN; specificity was calculated as TN/TN + FP. PPV was calculated as TP/TP + FP and NPV was calculated as TN/TN + FN. Sensitivity and specificity of screening instruments at their respective operational cutpoints were compared using the McNemar test.[19] ROC curves were obtained by plotting sensitivity on the y-axis against 1-specificity on the x-axis derived from the logistic regression model. Area under the ROC curve and associated 95% confidence intervals (CIs) were calculated.

RESULTS

Five thousand one hundred twenty-six participants, aged 55 and older, were recruited from 28 villages, representing a 99.84% response rate among all individuals aged 55 and older living in these villages. The EASI scale was administered to a reliable household member for each of the 5,126 subjects, including those that had recently died (n = 265) or were cognitively untestable (n = 47) usually because of

severe sensory impairment or physical illness. The remaining 4,810 completed cognitive screening. Of the 5,126 subjects who were thus cognitively and/or functionally screened, 536 (10.5%) were selected by the cognitive or functional impairment criteria described earlier and 270 (5.3%) were selected as unimpaired controls, for the standardized clinical diagnostic evaluation. Of these 806 subjects who were selected for clinical diagnostic evaluation, data were obtained on all three screening tools (the HMSE, the cognitive screening battery, and the EASI) from 632 subjects and/or their informants. The first set of calculations reported below and shown in the tables (sensitivity, specificity, PPV, and NPV) for the HMSE, EASI, and cognitive battery are based only on these 632 subjects who completed clinical diagnostic evaluation. Table 1 shows the number of subjects who underwent each component of the entire evaluation.

A second, similar, set of calculations is based on 4,810 subjects who completed all the screening instruments, including those who were not selected for clinical diagnostic evaluation (see Table 1). Only one of the 270 unimpaired controls was found to be demented, and this subject had suffered a stroke between screening and clinical evaluation. Thus, for the second set of calculations, we assumed that none of the subjects who were not diagnostically evaluated were demented; that is, we assumed a false negative rate of zero.

Demographic Characteristics

The study population had a mean age ± standard deviation of 66.5 ± 7.6, with a median of 65. Men constituted 53.1% of the cohort. Illiteracy (defined as inability to read a local newspaper and write a sentence) was found in 73.3% of the total cohort (95.4% of the women and 53.8% of the men).

Prevalence of Dementia

As reported previously, the overall prevalence of dementia was 0.84% (95% confidence interval (CI) = 0.61 to 1.13) based on the 43 individuals who met the criteria for dementia, with a CDR score of at least 0.5.[11] Eight of these 43 had died, and their diagnoses were made on the basis of family interviews. All calculations below are based only on the 32 cases of dementia that were clinically evaluated in person and had completed the HMSE, EASI, and cognitive battery.

Screening Properties (Sensitivity, Specificity, and Predictive Values)

Hindi Mental State Examination

Table 2 shows sensitivity, specificity, PPV, and NPV for dementia at HMSE scores ranging from 18 to 26. Our operational 10th percentile cutpoint on the general mental status test (HMSE score ≤19) had sensitivity of 81.3%, specificity of 60.2%, PPV of 9.8%, and NPV of 98.4% for dementia. Figure 1 shows the ROC curve for the HMSE. The area under the ROC curve was 0.804 (standard error (SE) = 0.047, 95% CI = 0.712–0.896).

For comparison, similar calculations were made using as the denominator all 4,810 subjects who completed the HMSE (regardless of whether they had been diagnostically evaluated). The corresponding figures at the 10th percentile cutpoint on the HMSE (≤19) were sensitivity of 81.3%, specificity of 93.4%, PPV of 8.0%, and NPV of 99.9%, assuming that none of the subjects not selected for clinical evaluation were demented.

Cognitive (Neuropsychological) Battery

The operational 10th percentile cutpoints on each test in the battery were the following scores: 1 on Word List Delayed Recall, 3 on Word List Learning, 10 on Verbal Fluency for fruits and animals, 13 on the Object Naming Test, and 3 on Constructional Praxis. The 10th percentile cutpoint on the neuropsychological battery as a whole (two-domain combination: memory test and at least one other test) produced a sensitivity of 81.3%, a specificity of 74.5%, PPV of 14.5%, and NPV of 98.7% for dementia, based on 632 subjects who completed the cognitive battery and clinical evaluation. For comparison, basing the calculations on all 4,810 subjects who completed the cognitive battery, the sensitivity was 81.3%, specificity was 96.0%, PPV was 12.0%, and NPV was 98.9% for dementia, assuming that none of the subjects not selected for clinical evaluation were demented. Because this screening tool is composed of varying combinations of multiple tests, each with its own 10th percentile cutpoint, it is not possible to generate a single ROC curve for this screening tool.

Functional Ability Scale–EASI

Table 3 shows sensitivity, specificity, PPV, and NPV for dementia of the EASI at cutpoints ranging from 1 to 5. At

Table 1. Subjects Completing the Various Screening Instruments and Diagnostic Evaluation

Description	Number of Subjects
Total number in cohort: all informants providing data on Everyday Abilities Scale for India informant questionnaire	5,126
Died before cognitive screening (n = 269) or cognitively untestable (n = 47)	316
Number cognitively screened (Hindi Mental State Examination + Cognitive Battery in person)	4,810
Total selected for clinical evaluation (impaired, n = 536; unimpaired controls, n = 270)	806
Diagnosed by in-person clinical evaluation (dementia, n = 32; no dementia, n = 600)	632
Diagnosed by family interview only (dementia, n = 11; no dementia, n = 163)	174
Total dementia cases (32 (diagnosed by in-person clinical evaluation) + 11 (diagnosed by family interview only))	43

Table 2. Dementia Sensitivity and Specificity for Various Cut Points of Hindi Mental State Examination (HMSE) Score with Corresponding Positive and Negative Predictive Values

HMSE Score	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value
	%			
18	75.0	74.8	13.7	98.3
19*	81.3	60.2	9.8	98.4
20	87.5	52.0	8.7	98.7
21	90.6	43.8	7.9	98.9
22	90.6	35.2	6.9	98.6
23	90.6	29.7	6.4	98.3
24	90.6	25.7	6.1	98.1
25	90.6	22.3	5.9	97.8
26	93.8	18.2	5.8	98.2

*Tenth percentile score on the HMSE.

the operational cutpoint of 3, these values were 62.5%, 89.7%, 24.4%, and 97.8%, respectively, based on the 632 subjects who underwent both EASI screening and clinical evaluation. Figure 2 shows the ROC curve for the EASI at this cutpoint. The area under the ROC curve was 0.884 (SE = 0.030, 95% CI = 0.824–0.943).

For comparison, in similar calculations based on all 4,810 subjects (n = 32 dementia cases) who were screened with both the EASI and HMSE, the sensitivity was 56.3%, specificity was 99.1%, PPV was 29.0%, and NPV was 97.8% for dementia using the same cutpoint. Similar calculations using the denominator of 5,126 subjects (n = 43 dementia cases) who were screened with the EASI alone (informant interview only) resulted in a sensitivity of 67.4%, specificity of 98.7%, PPV of 31.2%, and NPV of 99.7%, using the same cutpoint and assuming that none of the subjects not selected for clinical evaluation were demented.

Combinations of Screening Instruments

Table 4 shows the sensitivity, specificity, PPV, and NPV for different combinations of screening instruments, using the operational cutpoints established for this study. The highest possible pair of sensitivity (90.6%) and specificity (68.2%) figures was produced by the combination of the cognitive battery and EASI, with a PPV of 13.2% and an NPV of 99.3%. Of the 32 subjects screened by all three instruments who met the criteria for dementia, the HMSE missed six (i.e., screened negative on), the EASI missed 12, and the cognitive battery missed six. However, using, as we did, the combination of all three screening tools, only one demented subject was missed, and this subject was determined to have suffered cognitive and functional decline after a stroke that occurred subsequent to screening.

Comparisons of Screening Instruments

Sensitivity and specificity of all screening instruments at their respective operational cutpoints were compared using the McNemar test.[19]

Sensitivity At our operational cut points, the HMSE and EASI had sensitivities of 81.3% and 62.5% respectively (Tables 2 and 3). Despite the numerically large differences in these values, they were not significantly different by the McNemar test ($P = .083$) because of the low proportion of demented individuals in this sample. The combination of HMSE and EASI had a sensitivity of 90.6%, which was not ($P = .083$) significantly higher than that of the HMSE alone, but was significantly ($P = .003$) higher than that of the EASI alone (Table 4). The combination of the HMSE and the cognitive screening battery had a sensitivity of 90.6%, which, again, was numerically but not significantly higher than that of HMSE alone ($P = .083$) (Table 4).

Specificity At the same cutpoints, the EASI had a specificity of 89.7%, which was significantly higher ($P = .001$) than that of the HMSE (60.17%). The combination of HMSE and EASI had a specificity of 54.3%, which was significantly lower ($P < .001$) than that of the HMSE alone and the EASI alone. The combination of HMSE and the cognitive battery had a specificity of 46.0%, which was significantly ($P < .001$) lower than that of the HMSE alone.

Thus, neither the functional ability scale nor the cognitive battery significantly improved the sensitivity of the mental status test, and both significantly reduced the spec-

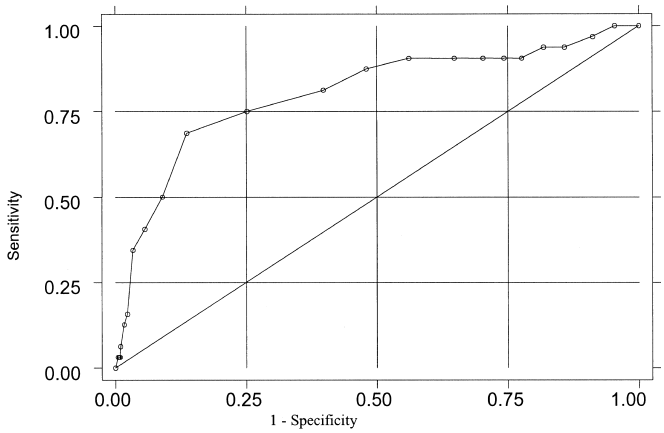

Figure 1. Receiver operating characteristic (ROC) curve for Hindi Mental State Examination. Area under ROC curve = 0.804 (standard error = 0.047, 95% confidence interval = 0.712–0.896).

Table 3. Sensitivity, Specificity, Positive and Negative Predictive Values for Dementia at Various Cut Points on the Everyday Abilities Scale for India (EASI)

	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value
EASI Score*			%	
1	96.9	45.3	8.6	99.6
2	90.6	67.7	14.4	99.3
3†	62.5	89.7	24.4	97.8
4	59.4	94.0	34.6	97.8
5	53.1	96.5	44.7	97.5

*Number of EASI items rated as "unable to perform."
†Operational cut point.

ificity. However, the functional ability scale, because it was administered to informants, led to the detection of 11 additional demented subjects in the cohort who were untestable, unavailable, or deceased.

DISCUSSION

The Hindi screening instruments used in this study were substantially modified and developed de novo for our Indian cohort, because existing English-language versions that work well in educated populations in the United States were clearly both culturally and linguistically inappropriate for a Hindi-speaking illiterate rural population in India. Overall, we found that our cognitive instruments had high sensitivity, whereas the functional instrument had high specificity for dementia. As expected from the low prevalence of dementia in this cohort,[11] PPV was low and NPV was high. At the study's operational cutpoints, the general mental status test (HMSE) and the functional ability questionnaire (EASI) had comparable sensitivity, whereas the latter had higher specificity and PPV. The neuropsychological battery had similar sensitivity to, and slightly higher specificity than, the HMSE. The combination of the battery with the functional scale had the highest sensitivity and specificity. These findings have several implications.

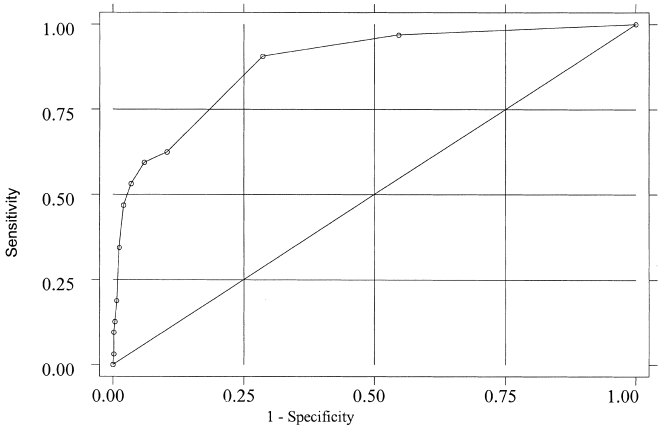

Figure 2. Receiver operating characteristic (ROC) curve for Everyday Abilities Scale for India. Area under ROC curve = 0.884 (standard error = 0.030, 95% confidence interval = 0.824–0.943).

Christensen et al.[20] performed a meta-analysis of four brief cognitive screening tests: the MMSE,[5] Short Portable Mental Status Questionnaire,[21] Mattis Dementia Rating Scale,[22] and the Blessed Dementia Rating Scale,[23] showing that all four had approximately the same ability to discriminate between subjects with and without dementia. In research and clinical settings, the most widely used brief general mental status test for dementia screening is the MMSE,[5] which has been translated into many languages worldwide. An average sensitivity of 83% and average specificity of 85% was found across 19 studies using the English language MMSE to screen for dementia.[24] In our own U.S. study in the Monongahela Valley of Pennsylvania (the MoVIES Project), the sensitivity and specificity of the MMSE at the 10th percentile of that cohort were 49.1% and 91.7%,[8] compared with the 81.3% and 60.2% observed at the 10th percentile of the HMSE in our Indian cohort. The conventional cutpoint of 23 on the MMSE was also at the 10th percentile of the MoVIES cohort. The cutpoint of 23 on the HMSE was at the 25th percentile in the Indian cohort; this cutpoint would have raised its sensitivity and lowered its specificity in the Indian cohort (see Table 2).

It is less common to use an entire battery of neuropsychological tests than a single brief cognitive scale for screening, but in our own U.S. study[8] we found a battery to have superior screening properties over the MMSE alone. The sensitivity and specificity of the neuropsychological battery (one memory test plus one other test) at the 10th percentile were 75.9% and 77.5%, respectively, in the Monongahela Valley,[8] compared with 81.3% and 74.5%, respectively, in Ballabgarh. However, in our U.S. study, the battery included additional tests (e.g., Story Recall, Trailmaking), which we were not able to adapt successfully for our Indian sample.[3,8] Although in our Indian study the addition of the cognitive battery did not significantly improve sensitivity, and significantly reduced the specificity, of the mental status test alone, it nevertheless provided valuable additional cognitive data at minimal extra cost.

The screening properties of any instrument will vary according to the cutpoint used, as shown in Tables 2 and 3, and the population in which it is being used. We adopted the percentile-based approach to setting cut points in both the U.S. and the Indian studies to avoid an excess of false positive screens in persons who obtained

Table 4. Sensitivity, Specificity, and Positive and Negative Predictive Values for Dementia of Various Combinations of Screening Instruments

Screening* Instrument	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value
	%			
HMSE + Cognitive Battery	90.6	46.0	8.2	98.9
HMSE + Cognitive Battery + EASI	93.8	41.8	7.9	99.2
HMSE + EASI	90.6	54.3	9.6	99.1
Cognitive Battery + EASI	90.6	68.2	13.2	99.3

*Tenth percentile cutpoint for Hindi Mental State Examination (HMSE) and Cognitive Battery and inability to perform three or more of the 11 items on Everyday Abilities Scale for India (EASI).

low test scores because, for example, of low education or illiteracy. In addition, the prevalence of dementia in a given population will also affect the predictive value of any screening instrument.

The DSM-III-R diagnostic criteria for dementia require that the observed cognitive impairment be sufficient to interfere with social and occupational functioning.[6] Particularly given our concern about how meaningful cognitive assessment might be in illiterate subjects, our study design included functional assessment in the screening protocol. Many existing scales assess ADLs and IADLs, most of which are designed to be administered to either the patient/subject or the family member/informant. Juva et al.[25] evaluated four functional (ADL and IADL) assessment scales and found that all detected dementia adequately with high sensitivity and specificity. At least one additional scale, the Informant Questionnaire on Cognitive Decline in the Elderly (IQCODE)[26] is designed specifically for administration to a reliable informant and inquires about decline in cognitive abilities relevant to daily functioning and observable by others. A meta-analysis of studies using the IQCODE showed that it performed as well as the MMSE in screening for dementia.[27] As noted, in comparing screening properties across studies, it is important to be aware of the nature of the populations and the prevalence of dementia among them.

For our community study in India, we developed de novo an informant-based functional ability questionnaire (EASI) that was appropriate to the local rural northern Indian setting and culture.[4] In terms of screening properties, we found that the EASI had lower sensitivity than both the HMSE and the battery, and the addition of the EASI to the HMSE did not significantly improve sensitivity, although it significantly reduced specificity. However, the EASI had the highest PPV of all our screening tools, and the combination of the EASI with the battery produced the best combination of sensitivity and specificity. It is worth emphasizing that the EASI was developed not as an all-purpose functional ability measure but specifically as a scale to help detect dementia and was determined during field testing to be strongly associated with the mental status test (HMSE). Of the dementia cases found during the prevalence survey reported here, a far greater proportion (53–95%) were reported by their families as having impairments in the various social interaction and cognitive function items on the EASI, compared with 37% to 40% on the personal care items. Although this difference might to some extent reflect severity of dementia, it also suggests that the scale is, as designed, oriented toward the heavily cognitively determined functional impairments expected in dementia.

As noted, the EASI was instrumental in obtaining relevant information from families of individuals who could not be cognitively tested, including those who were deceased. Although clinicians may not be interested in detecting dementia in deceased persons, this information can be useful in estimation of period prevalence within communities. Although our U.S. study included functional (ADL) questions, we did not use them for screening because not all our U.S. cohort members lived with families and had reliable informants, and self-report of functional ability may not be reliable in individuals with dementia. Because the EASI was newly developed for our illiterate rural older Indian population, it would not be meaningful to compare its sensitivity and specificity with that of, for example, the Older Americans Resources and Services ADL and IADL measures[28] used in many U.S. studies including our own. In societies where family structure is still relatively intact, and extended families live together, the presence of reliable informants is a rich resource that can provide an opportunity to assess functional ability and improve ability to detect dementia. However, in such societies, family members may minimize the failings of their aging parents both because of traditional respect for older relatives and because of low expectations of them.

The availability of resources for conducting research should also be considered when designing an approach to screening for dementia in a given population. If time for screening is at a premium, it is relevant that a brief general mental status test like the HMSE takes less time to administer than the neuropsychological battery, with no reduction in sensitivity and less than 3% reduction in specificity. However, the additional information gained from the neuropsychological battery might be valuable for diagnosis, prognosis, or hypothesis testing. In our U.S. study, interviewers with at least a bachelor's level education, who could be trained to administer and score neuropsychological tests, performed screening. In our Indian study, field workers with a high school education performed the screening; they were trained intensively to administer the tests and record subjects' responses verbatim, but an experienced neuropsychologist performed the scoring later. If personnel qualified to administer and interpret neuropsy-

chological tests are not available, it would be easier to train a field worker to administer the functional ability questionnaire to an informant than to develop and pilot neuropsychological tests and train and supervise workers in the administration of such tests. If research staff are readily available, and false positives can be removed during the second-stage clinical evaluation, it may be more important to use an instrument with good sensitivity (or at a cutpoint with good sensitivity) and be less concerned about specificity. These were the priorities in our own study, but priorities may vary across studies.

We have reported on our successful approach to screening for dementia in an illiterate population in a developing country setting. In our study, the combination of cognitive and functional screening elements appeared to optimize detection of dementia. As noted earlier, there is a dearth of adequate screening instruments for poorly educated populations, whether in clinical or research settings. Our approach to instrument development and application and our findings considering the relative merits of cognitive and functional screening in rural northern India may be of value in other developing countries. They may also be of interest, even in technologically developed countries, to clinicians and investigators who work with illiterate individuals and groups or with members of ethnic minorities who are not fluent or educated in the language of the dominant majority.

ACKNOWLEDGMENTS

At the Centre for Ageing Research, India, in New Delhi and Ballabgarh, we thank Dr. Vijay Chandra for local directorship of the project, participation in cognitive and functional scale development, and clinical evaluation of subjects. We thank Dr. Sujatha Sharma for participation in cognitive test development and for supervision and training of field workers in cognitive screening, Dr. Arun Mehta for software development and support, and staff of the Centre for Ageing Research in India and the Indo-U.S. Study. At the University of Pittsburgh, in Pittsburgh, we thank the investigators and staff of the Indo-U.S. Study. We are also grateful for the cooperation extended by Dr. Suresh Kapoor and other staff of the Comprehensive Rural Health Services Project (Centre for Community Medicine, All India Institute of Medical Sciences, New Delhi) for access to their Ballabgarh facilities and census database. Finally, we acknowledge the cooperation of the senior citizens of Ballabgarh for their participation in the study.

REFERENCES

1. World Health Organization (WHO). Population Ageing—A public health challenge. Fact Sheet No. 135. Geneva, Switzerland: World Health Organization, 1998.
2. Ganguli M, Ratcliff G, Chandra V et al. A Hindi version of the MMSE: The development of a cognitive screening instrument for a largely illiterate rural elderly population in India. Int J Geriatr Psychiatry 1995;10:367–377.
3. Ganguli M, Chandra V, Ratcliff G et al. Cognitive test performance in a community based non demented elderly sample in rural India: The Indo-US Cross-National Dementia Epidemiology Study. Int Psychogeriatr 1996;8: 507–524.
4. Fillenbaum G, Chandra V, Ganguli M et al. Development of an activities of daily living scale to screen for dementia in an illiterate rural older population in India. Age Ageing 1999;28:161–168.
5. Folstein MF, Folstein SE, McHugh PR. "Mini-mental state". A practical method of grading the cognitive state of patients for the clinician. J Psychiatric Research 1975;12:189–198.
6. American Psychiatric Association. Diagnostic and Statistical Manual of Mental Disorders, 3rd Ed, Revised. Washington, DC: American Psychiatric Association, 1987.
7. Ganguli M, Ratcliff G, Belle S et al. Effects of age, gender, and education on cognitive tests in and elderly rural community sample: Norms from the Monongahela Valley Independent Elders Survey (MoVIES). Neuroepidemiology 1991;10:42–52.
8. Ganguli M, Ratcliff G, Seaberg E et al. Sensitivity and specificity for dementia of population-based criteria for cognitive impairment: The MoVIES Project. J Gerontol 1993;48:M152–M161.
9. Chandra V, Ganguli M, Ratcliff G et al. Studies of the epidemiology of dementia: Comparisons between developed and developing countries. Aging Clin Exp Res 1994;6:307–321.
10. Chandra V, Ganguli M, Ratcliff G et al. Practical issues in cognitive screening of elderly illiterate populations in developing countries. The Indo-US Cross-National Dementia Epidemiology Study. Aging Clin Exp Res 1998;10: 349–357.
11. Chandra V, Ganguli M, Pandav R et al. Prevalence of Alzheimer's disease and other dementias in rural India. The Indo-US study. Neurology 1998;15: 1000–1008.
12. Morris JC, Heyman A, Mohs RC et al. The Consortium to Establish a Registry for Alzheimer's Disease (CERAD). Part I. Clinical and neuropsychological assessment of Alzheimer's disease. Neurology 1989;39:1159–1165.
13. Atkinson RC, Shiffrin RM. The control of short tem memory. Sci Am 1971; 221:82–90.
14. Kaplan EF, Goodglass GH, Weintraub S. The Boston Naming Test. Boston, MA: Lea and Febiger, 1983.
15. Benton AL, Hamsher K. Multilingual Aphasia Examination. Iowa City, IO: University of Iowa, 1976.
16. Rosen WG, Mohs RC, Davis KL. A new rating scale for Alzheimer's disease. Am J Psychiatry 1984;141:1356–1364.
17. Chandra V, DeKosky S, Pandav R et al. Neurological factors associated with cognitive impairment in a rural elderly population in India. The Indo-US Cross National Epidemiology Study. J Geriatr Psychiatry Neurol 1998;11:11–17.
18. Hughes CP, Berg L, Danziger WL et al. A new clinical scale for the staging of dementia. Br J Psychiatry 1982;140:566–572.
19. McNemar Q. Note on the sampling error of the difference between correlated proportions or percentages. Psychometrika 1947;12:153–157.
20. Christensen H, Hadzi-Pavlovic D, Jacomb P. The psychometric differentiation of dementia from normal aging; a meta analysis. Psychol Assess 1991;3: 147–155.
21. Pfeiffer E. A short portable mental status questionnaire for the assessment of organic brain deficit in elderly patients. J Am Geriatr Soc 1978;22:433–444.
22. Mattis S. Mental status examination for organic mental syndrome in the elderly patients. In: Bellak L, Karasu TB, eds. Geriatric Psychiatry. New York, NY: Grune & Stratton, 1976.
23. Blessed G, Tomlinson BE, Roth M. The association between quantitative measures of dementia and of senile change in the cerebral grey matter of elderly subjects. Br J Psychiatry 1968;114:797–811.
24. Tombaugh TN, McIntyre NJ. The Mini Mental State Examination: A comprehensive review. J Am Geriatr Soc 1992;40:922–935.
25. Juva K, Makela M, Erkinjunti T et al. Functional assessment scales in detecting dementia. Age Ageing 1997;26: 393–400.
26. Jorm AF, Scott R, Cullen JS et al. Performance of the Informant Questionnaire on Cognitive Decline in the Elderly (IQCODE) as a screening test for dementia. Psychol Med 1991;21:785–790.
27. Jorm AF. Methods of screening for dementia: A meta-analysis of studies comparing an informant questionnaire with a brief cognitive test. Alzheimer Dis Assoc Disord 1997;11:158–162.
28. Fillenbaum GG, Smyer MA. The development, validity, and reliability of the OARS multidimensional functional assessment questionnaire. J Gerontol 1981;36:428–434.