Diagnosis of Dementia

Methods for Interpretation of Scores of 5 Neuropsychological Tests

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Objective: To provide methods to interpret and compare different neurobehavioral screening tests for the diagnosis of dementia.

Design: Five mental-status neuropsychological tools for dementia screening were administered to patients in a memory disorder clinic. These included the Mini-Mental State Examination, the Dementia Rating Scale, the 6-item derivative of the Orientation-Memory-Concentration Test, a short Mental Status Questionnaire, and a composite tool we labeled the Ottawa Mental Status Examination, which assessed orientation, memory, attention, language, and visual-constructive functioning.

Results: To obtain *z* and percentile scores, norms are for the different tests, computed separately for patients with dementia of the Alzheimer type, vascular dementia, or no dementia. Another set of norms is reported in which a test score is translated directly into the posttest probability of dementia. Translation formulas are given to allow the estimation of the score on one test from the result on another test.

Conclusion: The interpretation of tests used to diagnose dementia must be based on an understanding of the meaning of an individual score, which is based on the question asked and the population to which the patient is referenced.

Arch Neurol. 1996;53:1043-1054

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IN A companion article in this issue,[1] we compared 5 standardized neuropsychological tools for diagnosis of dementia. If the goal is to have a tool for general screening of dementia, we recommended the Mini-Mental State Examination (MMSE) or Orientation-Memory-Concentration (OMC) Test. In addition to having the best statistical qualities, these tests are short. Our research goals in the present study were to provide methods for interpreting the test scores and to establish methods for translating scores obtained on one test into their equivalent on another test. The same database that was used by Stuss et al[1] was used as the basis for interpretations. The general background is described in that article.

RESULTS

In **Table 2** through **Table 13**, we give the normative data for our sample, which can be used to interpret individual test scores and compare different screening tests for dementia. Unless stated otherwise, the analyses were performed on the scores of patients whose native language was French or English and who were tested in their native language.

MEANS, SDs, AND PERCENTILE SCORES

In this section, all the patients with DAT (possible and probable) were joined in a single group to increase the sample size. Means and SDs are necessary to compute *z* scores. We report the means and SDs for the overall scores in Table 2. In Table 3, we report the means for the subscales of Dementia Rating Scale (DRS) and Ottawa Mental Status Examination (OMSE). Raw scores may be converted to percentile scores based on the results in Tables 4[3] through 8.

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PATIENTS AND METHODS

The patients and diagnostic procedures have been described.[1] Four types of dementia were considered in the analysis: probable dementia of the Alzheimer type (DAT), possible DAT, vascular dementia (VaD), and a group of mixed dementia types. Diagnosis of probable and possible DAT was based on National Institute of Neurological and Communicative Disorders and Stroke–Alzheimer's Disease and Related Disorders Association (NINCDS-ADRDA) criteria.[2] The 2 most common types of dementia were DAT and vascular dementia. A fifth group included approximately one fourth of the patients referred for memory problems and suspected Alzheimer disease who were eventually diagnosed as not having dementia. Demographic information is given in **Table 1**.

RELATING TEST SCORES TO LIKELIHOOD RATIOS AND POSTTEST PROBABILITY

Perhaps the most desired use of interpretation of test scores is to assign them directly to diagnosis. Using cutoff scores does precisely that. For example, with a cutoff of 23/24, an MMSE score of 20 is interpreted as pathological, whereas a score of 28 is interpreted as normal.

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Realistically, however, diagnosis always involves uncertainty, because a given test score might be obtained by patients with and without dementia. Eventually, the diagnostician needs to assign a degree of confidence (or probability) to the diagnosis. The norms reported in Tables 9 to 13 associate each test score with the probability that the patient has dementia as opposed to providing a dichotomous classification of dementia or no dementia.

Two sets of probabilities are assigned to each score. One set of probabilities is assigned to the score when it is interpreted in reference to a group diagnosed as having dementia (pathological). In this situation, the score is considered with all scores below it. For example, the score of 20 on the MMSE is considered with the scores of 0 to 19. The assigned probabilities reflect the chances that patients scoring 20 or lower have dementia. For OMC, high scores reflect worse performance, so the score is considered with the scores above it. The second set of probabilities is assigned to the same score when it is interpreted as normal. In this situation, it is considered with all the higher scores (or lower scores if the test is OMC). In the same example, the assigned probabilities reflect the chances that a patient scoring 20 or better on MMSE has dementia.

The interpretation of a specific score should be done in relation to a specific base rate. Consequently, each set of probabilities (pathological or normal) is subdivided according to the prevalence of dementia in the population from which the patient comes. Prevalence has a substantial influence on the chances of dementia for a given score. Research has shown that people, including experienced clinicians, are prone to a number of errors when they assign probabilities. Most notably, too much weight is given to the diagnostic value of the test (to what degree a given score indicates dementia), and the prevalence of the phenomenon in the reference population is underestimated or even ignored completely.[4] For example, a score of 20 on the MMSE is considered pathological. As our results show, some patients without dementia scored 20 or lower. The chances of encountering such a person in a clinical diagnostic situation depends on the percentage of persons without dementia in the population from

Table 1. Demographic Data of the Populations Studied*

	No. (%) of Patients†				
	Total DAT‡	Probable DAT	VaD	Misc	Nondemented
CDR rating					
0	4 (3)	...	3 (4)	11 (7)	82 (59)
1	94 (61)	36 (51)	57 (83)	103 (68)	56 (41)
2	38 (25)	18 (25)	7 (10)	34 (22)	...
3	18 (12)	17 (24)	2 (3)	5 (3)	...
Education					
Grade 1-8	59 (36)	26 (32)	33 (42)	72 (43)	48 (30)
High school	72 (42)	34 (43)	29 (37)	61 (37)	65 (40)
Undergraduate	31 (18)	15 (19)	15 (19)	24 (14)	31 (19)
Graduate	10 (6)	4 (5)	2 (3)	10 (6)	18 (11)
Sex					
Female	116 (66)	57 (70)	42 (52)	75 (44)	89 (54)
Male	61 (34)	24 (30)	39 (48)	95 (56)	77 (46)
Age, y					
Mean	71.8	71.6	73.3	70.9	61.4
Range	52-88	54-84	49-88	42-89	19-86

**DAT indicates Alzheimer disease; VaD, multi-infarct (vascular) dementia; Misc, those cases diagnosed as dementia with mixed types or types other than DAT or VaD; Nondemented, those cases referred for suspected dementia but eventually diagnosed as nondemented; and CDR, Clinical Dementia Rating Scale. Percentages are rounded. The total percentage may therefore not equal 100.*

†Unless otherwise indicated.

‡Total DAT includes patients in both the probable and possible classification.

Table 2. Norms for the Computation of *z* Scores for the 5 Screening Tests According to Type of Dementia*

Test	Type of Dementia, *z*			
	DAT	VaD	Misc	Nondemented
MMSE				
Mean	17.8	21.5	21.3	27.9
SD	7.2	6.0	6.5	2.9
No. of patients	164	76	159	146
OMC				
Mean	18.5	14.2	14.2	5.9
SD	7.0	6.7	7.1	5.1
No. of patients	163	76	158	145
MSQ				
Mean	4.8	6.2	6.6	8.9
SD	2.9	2.4	2.5	1.3
No. of patients	163	76	157	146
DRS				
Mean	106.0	112.6	113.6	132.5
SD	22.1	18.0	16.5	11.0
No. of patients	124	67	131	142
OMSE				
Mean	22.6	27.6	27.6	36.2
SD	9.6	7.8	8.6	3.9
No. of patients	163	76	158	146

**MMSE indicates Mini-Mental State Examination; OMC, Orientation-Memory-Concentration Test; MSQ, Mental Status Questionnaire; DRS; Dementia Rating Scale; and OMSE, Ottawa Mental Status Examination. Other abbreviations are given in Table 1.*

Table 3. Norms for the Computation of *z* Scores for the Subscales of DRS and OMSE According to Type of Dementia*

Subscales	Type of Dementia, *z*			
	DAT	VaD	Misc	Nondemented
DRS				
Attention				
Mean	34.1	34.6	35.0	35.8
SD	3.9	3.1	2.6	2.5
No. of patients	107	52	95	97
Initiation				
Mean	25.0	27.2	27.1	33.5
SD	7.9	6.3	6.7	4.2
No. of patients	107	52	95	97
Construction				
Mean	5.1	5.2	5.1	5.7
SD	1.5	1.6	1.4	0.9
No. of patients	107	52	95	97
Conceptualization				
Mean	28.1	29.6	30.7	35.7
SD	8.7	7.2	7.2	4.7
No. of patients	107	52	95	97
Memory				
Mean	13.1	15.1	16.5	21.4
SD	5.5	5.3	4.9	4.6
No. of patients	107	52	95	97
OMSE				
Orientation				
Mean	7.6	9.4	10.0	13.0
SD	4.0	3.7	3.7	1.5
No. of patients	137	59	113	100
Memory				
Mean	4.5	5.6	5.7	8.0
SD	2.2	1.8	2.3	1.6
No. of patients	136	59	112	100
Attention				
Mean	3.7	4.9	4.4	6.3
SD	2.8	2.2	2.7	1.5
No. of patients	136	59	112	100
Language				
Mean	6.1	6.7	6.4	7.5
SD	2.0	1.4	1.8	0.8
No. of patients	137	59	113	100
Copy				
Mean	0.6	0.6	0.6	0.9
SD	0.5	0.5	0.5	0.2
No. of patients	137	59	113	100

**Abbreviations and test names are given in Tables 1 and 2, respectively.*

which the person comes. The higher the proportion of persons without dementia, the greater the chances of finding a person who did not have dementia with a score of 20 or lower. In the normal population, multiple factors may contribute to a lower score (hence the "normal" curve), factors that do not imply a dementia. Thus, in a memory disorder clinic, the diagnosis of dementia based on an MMSE score at or below 20 is associated with high confidence (98%, according to our estimation), because in that setting, the chances are minimal of finding a person without dementia scoring that low. In contrast, the associated confidence for the same score of 20 is only 26% if the diagnosis is made in the community and the person is younger than 75 years. Nevertheless, most people find this reasoning counterintuitive and would assign similar degrees of confidence to a diagnosis of dementia regardless of the setting (memory disorder clinic vs the community). These errors in reasoning prevail even among persons with a background in statistical reasoning.

One way to overcome these biases is to relate a given test score directly to an estimated probability, thereby bypassing the need to make inferences from test scores. To achieve this goal, we determined the sensitivity and specificity corresponding to all possible cutoff points on the test. From sensitivity and specificity, we computed 2 likelihood ratios for each test score. The pathological likelihood ratio (PLR) corresponds to scores equal to or worse than the given score. Another variable was the normal likelihood ratio (NLR), which corresponds to scores equal to or better than the given score. Using a likelihood ratio is a convenient way of applying the Bayes theorem in a practical setting.

To make use of the norms easy, we computed posttest probabilities that are associated with any given test score. We shall first explain how these probabilities were computed and then explain how to use the norms.

The computation of posttest probabilities was performed in 4 steps[5]:

1. Percentages were translated into pretest odds using the following formula: odds=percent/(100−percent) or odds=probability/(1−probability).

According to this formula, 20% is equivalent to odds of 1 in 4 (1 person with dementia for every 4 persons without dementia). Pretest odds reflect the base rate, or the chances that the person has dementia based only on the knowledge about the population from which the patient comes.

2. Each test score was associated with PLR and NLR, which are reported in Tables 9 to 13. These values were

Table 4. Percentile Scores on MMSE According to Type of Dementia*

Score	Type of Dementia, Percentile Scores			
	DAT	VaD	Nondemented	All
0-1	2	0	0	1
2	3	0	0	1
3	3	1	0	1
4	4	1	0	2
5	6	1	0	3
6	7	1	0	3
7	8	1	0	4
8	10	2	0	5
9	13	3	0	6
10	16	3	0	7
11	18	5	0	9
12	21	7	0	11
13	25	9	0	12
14	29	11	0	14
15	34	14	0	17
16	39	20	1	20
17	44	25	2	24
18	49	30	2	27
19	53	34	3	30
20	57	38	4	34
21	61	43	4	37
22	65	47	5	41
23	70	53	7	46
24	77	59	9	51
25	83	64	12	56
26	87	72	17	62
27	91	80	25	6
28	95	87	36	76
29	98	92	54	84
30	99	97	83	94

**All indicates patients with dementia regardless of type. Other abbreviations and test names are given in Tables 1 and 2, respectively. See Crum et al[3] for the effects of age and education. Our nondemented group is likely not representative of the normal population. It reflects more the type of nondemented individual referred to a memory clinic, suggesting that the scores presented herein may be more helpful for differential diagnoses. Underlined scores refer to examples in the text.*

computed based on the data in our database. For example, an MMSE score of 18 is associated with a PLR of 20 and an NLR of 0.46 (Table 8).

3. Posttest odds were computed. These odds reflect the chance that the patient has dementia and allow for the base rate and the test score. Posttest odds are the product of pretest odds and PLR or NLR. If the score is interpreted as pathological (the score is considered with the scores that reflect worse performance), posttest odds=pretest odds×PLR. If the score is interpreted as normal (the score is considered with the scores that reflect better performance), posttest odds=pretest odds×NLR.

Using the values in the example, the corresponding odds for an MMSE score of 18 when interpreted as pathological are 20×1/4=5 (5 patients with dementia for every patient without dementia), and when interpreted as normal are 0.46×1/4=0.115 (0.115 patients with dementia for every patient without dementia).

4. Posttest odds were converted into probabilities using the following formula: probability=odds/(1+odds). For example, the obtained posttest odds of 5 correspond to 5/(1+5)=0.83, or 83%.

Table 5. Percentile Scores on OMC According to Type of Dementia*

Score	Type of Dementia, Percentile Scores			
	DAT	VaD	Nondemented	All
28	9	2	0	4
27	18	4	0	7
26	19	5	0	8
25	22	9	0	10
24	29	12	0	14
23	33	14	0	16
22	36	15	0	18
21	42	18	1	21
20	47	22	2	25
19	48	24	3	26
18	51	28	3	29
17	56	32	5	34
16	62	36	7	38
15	64	39	7	39
14	67	45	8	43
13	72	54	10	48
12	77	61	12	52
11	79	63	13	54
10	87	70	18	61
9	94	78	23	67
8	96	82	29	72
7	98	86	37	76
6	98	89	42	79
5	99	91	48	81
4	99	94	56	85
3	99	97	64	88
2	99	99	74	91
1	99	100	84	95
0	100	100	92	97

**All indicates patients with dementia regardless of type. Other abbreviations and test names are given in Tables 1 and 2, respectively.*

Table 6. Percentile Scores on MSQ According to Type of Dementia*

Score	Type of Dementia, Percentile Scores			
	DAT	VaD	Nondemented	All
0	2	0	0	1
1	10	2	0	4
2	22	6	0	9
3	33	11	0	15
4	44	20	1	21
5	51	33	2	28
6	60	45	4	37
7	71	57	8	46
8	82	70	16	58
9	93	87	42	75
10	99	97	81	93

**All indicates patients with dementia regardless of type. Other abbreviations and test names are given in Tables 1 and 2, respectively.*

We computed posttest scores associated with some typical prevalence values and expressed the results in probabilities rather than odds to make them readily interpretable. The prevalence values for which we made these computations were 2%, which is approximately the prevalence of dementia in the community for people aged 65 to 74 years.[6] Ten percent corresponds to the prevalence of dementia among

Table 7. Percentile Scores on the DRS According to Type of Dementia*

Score	Type of Dementia, Percentile Scores			
	DAT	VaD	Nondemented	All
22-26	1	0.00	0.00	0.00
27-49	2	0.00	0.00	0.00
50-57	2	1	0.00	1
58	3	1	0.00	1
59	3	1	0.00	1
60	4	1	0.00	1
61	4	1	0.00	1
62	4	1	0.00	1
63	5	1	0.00	2
64	5	1	0.00	2
65	6	1	0.00	2
66	6	1	0.00	2
67	6	1	0.00	2
68	6	1	0.00	2
69	7	1	0.00	2
70	8	1	0.00	2
71	8	2	0.00	3
72	9	3	0.00	3
73	9	3	1	3
74	9	3	1	4
75	10	3	1	4
76	11	4	1	4
77	12	4	1	5
78	13	4	1	5
79	13	4	1	5
80	14	4	1	6
81	15	4	1	6
82	15	4	1	6
83	15	4	1	7
84	15	4	1	7
85	16	6	1	8
86	16	8	1	8
87	16	9	1	8
88	17	10	1	9
89	17	10	1	9
90	18	11	1	9
91	19	13	1	10
92	20	16	1	11
93	21	16	1	12
94	23	16	1	12
95	24	16	1	13
96	25	16	1	14
97	26	16	1	14
98	28	16	1	15
99	29	17	2	16

Table 7. Percentile Scores on the DRS According to Type of Dementia* (cont)

Score	Type of Dementia, Percentile Scores			
	DAT	VD	Nondemented	All
100	31	19	2	17
101	34	19	2	19
102	36	19	3	20
103	38	20	3	20
104	39	24	3	21
105	40	28	3	22
106	41	30	3	23
107	42	32	3	25
108	43	37	3	27
109	45	41	4	29
110	46	43	4	30
111	49	46	4	31
112	52	50	4	33
113	55	52	5	35
114	58	54	6	37
115	60	55	7	39
116	63	55	8	41
117	66	57	8	43
118	68	60	10	45
119	70	63	12	48
120	72	65	14	50
121	74	66	14	52
122	77	66	15	54
123	79	66	17	56
124	81	69	18	58
125	83	70	19	59
126	85	72	20	61
127	87	74	23	63
128	89	75	24	65
129	91	76	25	67
130	92	77	28	69
131	92	82	30	70
132	92	88	32	72
133	94	90	35	74
134	95	92	38	76
135	97	93	42	78
136	98	95	48	81
137	98	96	56	84
138	98	96	65	87
139	99	97	73	90
140	99	99	78	92
141	99	100	83	94
142	99	100	89	96
143	100	100	95	98
144	100	100	99	100

**All indicates patients with dementia regardless of type. Other abbreviations and test names are given in Tables 1 and 2, respectively. Underlined scores refer to examples in the text.*

medical inpatients who are younger than 84 years; 20% is approximately the prevalence in the community for persons between 74 and 85 years; 50% is approximately the prevalence in nursing homes and in the community for persons older than 85 years; 75% is the prevalence in our sample, which is probably representative of memory disorder clinics. To use the norms, choose the prevalence that you believe matches the setting you work with and ignore all other columns. Two probabilities were computed, one for the score as considered pathological, the other for the same score considered as normal. For example, assume that testing is performed in a nursing home in which prevalence is about 50%. If a patient obtained an MMSE score of 17, the probabilities given in Table 9 are 96% when the score is considered as pathological and 34% when it is considered as normal. In other words, using the assumption of dementia (left side of Table 9, pathological), the same score of 17 is interpreted as a diagnosis of dementia (96%). If the score is interpreted as indicating normal performance (right side of Table 9), the patient has a 34% chance of having dementia. Hence, the score probably indicates that this patient has dementia. The score can be safely interpreted as pathological (leaving room

Table 8. Percentile Scores on OMSE According to Type of Dementia*

Score	Type of Dementia, Percentile Scores			
	DAT	VaD	Nondemented	All
0-1	2	0	0	0
2-3	3	0	0	1
4	3	1	0	1
5	4	1	0	2
6	5	1	0	2
7	7	1	0	3
8	8	1	0	4
9	9	1	0	4
10	12	2	0	5
11	15	3	0	6
12	16	3	0	7
13	18	5	0	8
14	20	6	0	10
15	23	8	0	11
16	26	9	0	13
17	29	10	0	14
18	32	11	0	16
19	35	13	1	17
20	39	16	1	20
21	43	18	1	22
22	48	24	1	25
23	51	30	2	27
24	53	34	2	29
25	57	37	3	32
26	59	40	4	34
27	60	44	4	37
28	63	48	4	40
29	67	51	5	43
30	70	53	7	46
31	75	57	10	50
32	79	61	13	55
33	83	68	15	58
34	88	76	18	63
35	92	82	24	68
36	95	88	33	74
37	98	93	43	80
38	98	95	62	87
39	99	98	84	95
40	100	100	96	99

**All indicates patients with dementia regardless of type. Other abbreviations and test names are given in Tables 1 and 2, respectively.*

for only 100%−96%=4% chances of error), and cannot be interpreted safely as normal, because the chances for error associated with this interpretation are 34%. The table does not begin with the lowest possible score and ends before the highest possible score, because no patients without dementia scored below a given score and no patients with dementia scored above a given score. Scores lower than those included in the tables (indicating dementia) or higher than those indicated in the tables (indicating not having dementia) should, therefore, be associated with high degrees of certainty.

HOW TO COMPUTE NORMS FOR PREVALENCE RATIOS THAT ARE NOT INCLUDED IN THE TABLES

The tables include norms for typical prevalence ratios. However, one may wish to compute norms for a prevalence ratio that is not included. For this purpose, PLR and NLR for each test score are reported on the left side of the tables. To obtain the norms, estimate the prevalence of dementia for which you wish to compute the norms and follow the aforementioned steps 1 to 4.

TAILORED CUTOFF POINTS

The norms can be used to establish cutoff points tailored to a setting (prevalence). To do that, a convention is needed about the desired certainty of the diagnosis. We are unaware of an existing convention and, therefore, suggest a convention that considers the diagnostic needs typical for a given setting. Consider first a positive diagnosis. In the community, low levels of confidence (70%) are sufficient to establish a positive diagnosis, because the person is likely to be referred for a more extensive follow-up. In contrast, high levels of confidence should be associated with a positive diagnosis in a memory disorder clinic. We suggest a level of confidence of at least 0.95.

For a negative diagnosis, we suggest that the convention be a probability close to that of persons in a similar age in the community. A convention for negative diagnosis is needed in settings such as nursing homes and memory disorder clinics, where ruling out the possibility of dementia is likely to affect important decisions about the person being tested. In other words, to rule out dementia, the test score should be associated with a normal (right side of columns in tables) posttest probability of about 2% for persons aged 65 to 74 years or 20% for persons older than 74 years.

We provide some examples of how these conventions are applied. Consider first a positive diagnosis for persons older than 74 years in the community. According to Siu,[6] the prevalence of dementia in the community for persons in the age range 74 to 85 years is about 20%. Therefore, the relevant columns are for pathological diagnosis (left side) and prevalence of 20% (middle column), where we looked for values close to 0.70. These considerations led us to suggest the following cutoffs: 23/24 for MMSE (because the confidence level for a score of 23 is 0.72 when prevalence of dementia is 20%, Table 9), 15/14 for OMC (confidence level of 0.73 for a score of 15, Table 10), and 116/117 on DRS (confidence level of 0.73 for a score of 116, Table 12).

Cutoffs for a memory disorder clinic (prevalence of 75%) were determined using the convention of pathological diagnosis with a confidence level of at least 0.95. These are 25 or lower for MMSE, 11 or higher for OMC, and 120 or lower for DRS (Tables 9, 10, and 12, respectively, under Pathological Diagnosis and the column associated with prevalence of 0.75).

In a memory disorder clinic, a high score can lead to the rejection of the possibility of dementia. If the score is so high that the probability for dementia associated with a negative diagnosis is as low as that in the community, the patient should be considered as not having dementia. For persons older than 74 years, this rate is about 0.20. Hence, the recommended upper cutoffs are MMSE=27 or more (far right column, Table 9, where the associated posttest probability for normal diagnosis is 0.23),

Table 9. Likelihood Ratios for Pathological and Normal Diagnoses as a Function of MMSE Score and Prevalence*

MMSE Score	PLR	NLR	Diagnosis,† Likelihood Ratio: Pathological, % Prevalence 2	10	20	50	75	Normal, % Prevalence‡ 2	10	20	50	75
16	49.0	...	0.50	0.84	0.92	0.98	0.99	...	...	...	...	...
17	27.5	0.52	0.36	0.75	0.87	0.96	0.99	0.01	0.05	0.12	0.34	0.61
18	20.0	0.46	0.29	0.69	0.83	0.95	0.98	0.01	0.05	0.10	0.32	0.58
19	21.3	0.41	0.30	0.70	0.84	0.96	0.98	0.01	0.04	0.09	0.29	0.55
20	17.0	0.37	0.26	0.65	0.81	0.94	0.98	0.01	0.04	0.08	0.27	0.53
21	14.2	0.33	0.22	0.61	0.78	0.93	0.98	0.01	0.04	0.08	0.25	0.50
22	12.5	0.31	0.20	0.58	0.76	0.93	0.97	0.01	0.03	0.07	0.24	0.48
23	10.4	0.27	0.17	0.54	0.72	0.91	0.97	0.01	0.03	0.06	0.21	0.45
24	8.50	0.18	0.15	0.49	0.68	0.89	0.96	0.00	0.02	0.04	0.15	0.35
25	6.29	0.17	0.11	0.41	0.61	0.86	0.95	0.00	0.02	0.04	0.15	0.34
26	4.38	0.14	0.08	0.33	0.52	0.81	0.93	0.00	0.02	0.03	0.12	0.30
27	3.20	0.10	0.06	0.26	0.44	0.76	0.91	0.00	0.01	0.02	0.09	0.23
28	...	0.06	...	...	...	...	...	0.00	0.01	0.01	0.06	0.15

*Likelihood ratio indicates probability of having Alzheimer disease; PLR, likelihood ratio for pathological result (less than or equal score); and NLR, likelihood ratio for normal result (greater than or equal score). Test names are given in Table 2. Underlined numbers refer to examples in the text.

†The diagnosis of the score as normal is based on scores equal to or better than the given score. A diagnosis of the score as pathological is based on scores worse than or equal to the given score.

‡Typical prevalence values are 2% (community ages, 65-74 years), 10% (medical inpatients), 20% (community ages, 74-85 years), 50% (community older than 85 years and nursing homes), and 75% (memory clinics).

Table 10. Likelihood Ratios for Pathological and Normal Diagnoses as a Function of OMC Score and Prevalence*

OMC	PLR	NLR	Diagnosis, Likelihood Ratio: Pathological, % Prevalence 2	10	20	50	75	Normal, % Prevalence 2	10	20	50	75
22	43.0	...	0.47	0.83	0.91	0.98	0.99	...	...	...	...	...
21	27.5	0.58	0.36	0.75	0.87	0.96	0.99	0.01	0.06	0.13	0.37	0.64
20	18.3	0.46	0.27	0.67	0.82	0.95	0.98	0.01	0.05	0.10	0.32	0.58
19	18.3	0.46	0.27	0.67	0.82	0.95	0.98	0.01	0.05	0.10	0.32	0.58
18	20.3	0.46	0.29	0.69	0.84	0.95	0.98	0.01	0.05	0.10	0.32	0.58
17	11.7	0.40	0.19	0.56	0.74	0.92	0.97	0.01	0.04	0.09	0.29	0.55
16	10.4	0.32	0.18	0.54	0.72	0.91	0.97	0.01	0.03	0.07	0.24	0.49
15	10.6	0.29	0.18	0.54	0.73	0.91	0.97	0.01	0.03	0.07	0.22	0.47
14	7.60	0.28	0.13	0.46	0.66	0.88	0.96	0.01	0.03	0.07	0.22	0.46
13	7.27	0.27	0.13	0.45	0.65	0.88	0.96	0.01	0.03	0.06	0.21	0.45
12	6.23	0.22	0.11	0.41	0.61	0.86	0.95	0.00	0.02	0.05	0.18	0.40
11	6.23	0.22	0.11	0.41	0.61	0.86	0.95	0.00	0.02	0.05	0.18	0.40
10	4.13	0.22	0.08	0.31	0.51	0.81	0.93	0.00	0.02	0.05	0.18	0.40
9	4.13	0.06	0.08	0.31	0.51	0.81	0.93	0.00	0.01	0.01	0.06	0.15
8	2.69	0.06	0.05	0.23	0.40	0.73	0.89	0.00	0.01	0.01	0.06	0.15
7	2.68	0.05	0.05	0.23	0.40	0.73	0.89	0.00	0.01	0.01	0.05	0.13
6	...	0.02	...	...	...	...	...	0.00	0.00	0.00	0.02	0.06

*Test names are given in Table 2. Other abbreviations and definitions are given in Table 9.

OMC=9 or lower (associated probability=0.15, Table 10), and DRS=127 or higher (associated probability=0.21, Table 12).

Assume, for example, that a patient older than 85 years is tested in a memory disorder clinic. A score of 24 or less on the MMSE would suggest an 89% probability of having dementia and only 15% of not having dementia. A score of 24 can occur for many reasons other than dementia (hence the probability of 15% that the patient does not have dementia), but the probability of dementia is much higher. A score of 27 or higher should lead to a negative diagnosis. An MMSE score of 26 is uninformative in a memory disorder clinic in the sense that the posttest probability is close to the pretest probability. Similarly, based on our norms, an OMC score of 10 and DRS scores between 121 and 126 are uninformative.

CUTOFF POINTS

We do not recommend the use of cutoff points. Nevertheless, cutoff points may be useful in some circumstances. Therefore, we generated a set of recommended cutoff points based on our data.[1]

Table 11. Likelihood Ratios for Pathological and Normal Diagnoses as a Function of MSQ Score and Prevalence*

			Diagnosis, Likelihood Ratio									
			Pathological, % Prevalence					Normal, % Prevalence				
MSQ	PLR	NLR	2	10	20	50	75	2	10	20	50	75
4	57.0	...	0.54	0.86	0.93	0.98	0.99	...	...	...	...	...
5	19.3	0.43	0.28	0.68	0.83	0.95	0.98	0.01	0.05	0.10	0.30	0.56
6	14.6	0.43	0.23	0.62	0.78	0.94	0.98	0.01	0.05	0.10	0.30	0.56
7	7.64	0.28	0.13	0.46	0.66	0.88	0.96	0.01	0.03	0.07	0.22	0.46
8	4.00	0.18	0.08	0.31	0.50	0.80	0.92	0.00	0.02	0.04	0.15	0.35
9	1.60	0.15	0.03	0.15	0.29	0.62	0.83	0.00	0.02	0.04	0.13	0.31
10	...	0.03	...	...	...	...	...	0.00	0.00	0.01	0.03	0.08

*Test names are given in Table 2. Other abbreviations and definitions are given in Table 9.

CONVERSION FORMULAS

Conversion formulas are required when a patient is referred from a clinic that does not use the same screening test. The results of the principal component analysis show that conversion of scores is justified, because all the tests measure the same process or set of processes. Unfortunately, our results and those of others[5] indicate that the formulas are not sufficiently precise to be applicable for this purpose. The formulas can, nevertheless, be used to compare between groups of patients, eg, to compare between studies that used different screening tools. Previously published conversion formulas that were based on patients with Alzheimer disease can be applied only to similar patients. The conversion formulas that we computed are given in **Table 14**. Results from previous studies are given in **Table 15**.[7-9]

Before estimating these regression formulas, we tested for the possibility that the linear relations between any pair of tests are mediated by type of dementia. This was accomplished by predicting a score on one test by dementia type, the other test, and the difference in regression weights between dementia types. The difference in regression weights did not reach significance when OMC was not involved and reached significance in every case when OMC was involved.

For this reason, we estimated the regression formulas on the entire sample and estimated separate formulas for different dementia types when OMC was involved in the model. About 70% of the population should have their true score in the range of predicted score plus or minus root mean square error. As one may see, root mean square error (RMSE) values are large and make it impractical to use the formulas on individual patients.

USE OF THE TEST RESULTS

The mental-status tests used were the MMSE, the OMC Test, the Mental Status Questionnaire (MSQ), the DRS, and the OMSE.[1] They were given in the standard format, with the exception that Canadian content replaced American content (eg, "What is the name of the prime minister of Canada?"). The results can be used for 2 general purposes: to interpret individual scores and to compare scores of a patient on one test with his or her score on another test. We give examples to assist in using the norms.

INTERPRETATION OF INDIVIDUAL TEST SCORES

Does a score of 26 on the MMSE indicate that the patient has dementia? To answer this question, 4 different ways to interpret an individual test score are given. The method selected often relates to the specific diagnostic question being asked.

One procedure is to convert the individual score into a standard (z) score so that comparison can be made on a linear scale. In a standard score, zero is the mean, and about 70% of the z scores fall between -1 and $+1$. A z score is obtained by subtracting the group mean score from the individual score of 26, and then dividing this result by the group SD. For example, for the patients in our sample who had DAT, the mean and SD of the MMSE are 17.8 and 7.2, respectively (Table 2). The z score for the patient with a score of 26 is $(26-17.8)/7.2=1.1$. This result indicates that the patient's score is more than 1 SD above the mean of patients with DAT. A z score also can be computed for a different comparison group, such as the patients without dementia (mean=27.9, SD=2.9, Table 2). In this comparison, the patient's z score is $(26\text{-}27.9)/2.9=-0.7$. Using this comparison group, the patient's score is below the average of patients without dementia. This test score, then, interpreted against the background of 2 different comparison groups, suggests that the patient should be observed, or that other causes for decreased performance be sought. The performance is less than expected for a normal population but not representative of most patients with DAT.

A second approach is to convert the raw score to percentiles. This approach addresses the question, How many patients score worse than or as well as that patient (Table 4)? The 87% of patients with DAT have a score worse than or equal to 26 on the MMSE. In contrast, the same score is low among patients without dementia, only 17% of whom score equal to or worse than 26. The interpretation is similar to that for the z score. Percentiles may be easier to understand.

A third approach to interpret a test score is to relate it directly to the probability that the patient has dementia. To do this, the interpreter needs to know the prevalence of dementia among the patients tested, because a true estimate of probability depends on the base rate in a defined population. That is, in establishing di-

Table 12. Likelihood Ratios for Pathological and Normal Diagnoses as a Function of DRS Score and Prevalence*

			Diagnosis, Likelihood Ratio									
			Pathological, % Prevalence					Normal, % Prevalence				
DRS	PLR	NLR	2	10	20	50	75	2	10	20	50	75
73	13.0	...	0.21	0.59	0.76	0.93	0.98	...	...	...	...	...
74	15.0	0.88	0.23	0.62	0.79	0.94	0.98	0.02	0.09	0.18	0.47	0.73
75	16.0	0.86	0.25	0.64	0.80	0.94	0.98	0.02	0.09	0.18	0.46	0.72
76	16.0	0.85	0.25	0.64	0.80	0.94	0.98	0.02	0.09	0.18	0.46	0.72
77	18.0	0.85	0.27	0.67	0.82	0.95	0.98	0.02	0.09	0.18	0.46	0.72
78	20.0	0.83	0.29	0.69	0.83	0.95	0.98	0.02	0.08	0.17	0.45	0.71
79	20.0	0.81	0.29	0.69	0.83	0.95	0.98	0.02	0.08	0.17	0.45	0.71
80	22.0	0.81	0.31	0.71	0.85	0.96	0.99	0.02	0.08	0.17	0.45	0.71
81	22.0	0.79	0.31	0.71	0.85	0.96	0.99	0.02	0.08	0.16	0.44	0.70
82	22.0	0.79	0.31	0.71	0.85	0.96	0.99	0.02	0.08	0.16	0.44	0.70
83	22.0	0.79	0.31	0.71	0.85	0.96	0.99	0.02	0.08	0.16	0.44	0.70
84	24.0	0.79	0.33	0.73	0.86	0.96	0.99	0.02	0.08	0.16	0.44	0.70
85	24.0	0.77	0.33	0.73	0.86	0.96	0.99	0.02	0.08	0.16	0.44	0.70
86	24.0	0.77	0.33	0.73	0.86	0.96	0.99	0.02	0.08	0.16	0.44	0.70
87	24.0	0.77	0.33	0.73	0.86	0.96	0.99	0.02	0.08	0.16	0.44	0.70
88	24.0	0.77	0.33	0.73	0.86	0.96	0.99	0.02	0.08	0.16	0.44	0.70
89	24.0	0.77	0.33	0.73	0.86	0.96	0.99	0.02	0.08	0.16	0.44	0.70
90	24.0	0.77	0.33	0.73	0.86	0.96	0.99	0.02	0.08	0.16	0.44	0.70
91	27.0	0.77	0.36	0.75	0.87	0.96	0.99	0.02	0.08	0.16	0.44	0.70
92	27.0	0.74	0.36	0.75	0.87	0.96	0.99	0.01	0.08	0.16	0.43	0.69
93	27.0	0.74	0.36	0.75	0.87	0.96	0.99	0.01	0.08	0.16	0.43	0.69
94	29.0	0.74	0.37	0.76	0.88	0.97	0.99	0.01	0.08	0.16	0.43	0.69
95	33.0	0.72	0.40	0.79	0.89	0.97	0.99	0.01	0.07	0.15	0.42	0.68
96	33.0	0.68	0.40	0.79	0.89	0.97	0.99	0.01	0.07	0.15	0.40	0.67
97	33.0	0.68	0.40	0.79	0.89	0.97	0.99	0.01	0.07	0.15	0.40	0.67
98	36.0	0.68	0.42	0.80	0.90	0.97	0.99	0.01	0.07	0.15	0.40	0.67
99	18.0	0.65	0.27	0.67	0.82	0.95	0.98	0.01	0.07	0.14	0.39	0.66
100	19.0	0.65	0.28	0.68	0.83	0.95	0.98	0.01	0.07	0.14	0.39	0.66
101	14.0	0.63	0.22	0.61	0.78	0.93	0.98	0.01	0.07	0.14	0.39	0.65
102	15.0	0.60	0.23	0.62	0.79	0.94	0.98	0.01	0.06	0.13	0.38	0.64
103	15.0	0.57	0.23	0.62	0.79	0.94	0.98	0.01	0.06	0.12	0.36	0.63
104	15.0	0.57	0.23	0.62	0.79	0.94	0.98	0.01	0.06	0.12	0.36	0.63
105	15.0	0.57	0.23	0.62	0.79	0.94	0.98	0.01	0.06	0.12	0.36	0.63
106	16.3	0.57	0.25	0.64	0.80	0.94	0.98	0.01	0.06	0.12	0.36	0.63
107	16.3	0.53	0.25	0.64	0.80	0.94	0.98	0.01	0.06	0.12	0.35	0.61
108	12.8	0.53	0.21	0.59	0.76	0.93	0.97	0.01	0.06	0.12	0.35	0.61
109	13.8	0.51	0.22	0.60	0.77	0.93	0.98	0.01	0.05	0.11	0.34	0.60
110	14.0	0.47	0.22	0.61	0.78	0.93	0.98	0.01	0.05	0.11	0.32	0.59
111	14.5	0.46	0.23	0.62	0.78	0.94	0.98	0.01	0.05	0.10	0.32	0.58
112	15.5	0.44	0.24	0.63	0.79	0.94	0.98	0.01	0.05	0.10	0.31	0.57
113	12.8	0.40	0.21	0.59	0.76	0.93	0.97	0.01	0.04	0.09	0.29	0.55
114	10.7	0.38	0.18	0.54	0.73	0.91	0.97	0.01	0.04	0.09	0.28	0.53
115	8.38	0.38	0.15	0.48	0.68	0.89	0.96	0.01	0.04	0.09	0.28	0.53
116	9.38	0.36	0.16	0.51	0.70	0.90	0.97	0.01	0.04	0.08	0.26	0.52
117	8.44	0.27	0.15	0.48	0.68	0.89	0.96	0.01	0.03	0.06	0.21	0.45
118	6.91	0.26	0.12	0.43	0.63	0.87	0.95	0.01	0.03	0.06	0.21	0.44
119	6.15	0.27	0.11	0.41	0.61	0.86	0.95	0.01	0.03	0.06	0.21	0.45
120	6.00	0.23	0.11	0.40	0.60	0.86	0.95	0.00	0.02	0.05	0.19	0.41
121	5.67	0.19	0.10	0.39	0.59	0.85	0.94	0.00	0.02	0.05	0.16	0.36
122	5.44	0.18	0.10	0.38	0.58	0.84	0.94	0.00	0.02	0.04	0.15	0.35
123	4.83	0.15	0.09	0.35	0.55	0.83	0.94	0.00	0.02	0.04	0.13	0.31
124	4.83	0.16	0.09	0.35	0.55	0.83	0.94	0.00	0.02	0.04	0.14	0.32
125	4.79	0.16	0.09	0.35	0.54	0.83	0.93	0.00	0.02	0.04	0.14	0.32
126	4.23	0.11	0.08	0.32	0.51	0.81	0.93	0.00	0.01	0.03	0.10	0.25
127	4.04	0.09	0.08	0.31	0.50	0.80	0.92	0.00	0.01	0.02	0.08	0.21
128	4.00	0.09	0.08	0.31	0.50	0.80	0.92	0.00	0.01	0.02	0.08	0.21
129	3.56	0.05	0.07	0.28	0.47	0.78	0.91	0.00	0.01	0.01	0.05	0.13
130	3.31	0.05	0.06	0.27	0.45	0.77	0.91	0.00	0.01	0.01	0.05	0.13
131	3.10	0.06	0.06	0.26	0.44	0.76	0.90	0.00	0.01	0.01	0.06	0.15
132	2.82	0.06	0.05	0.24	0.41	0.74	0.89	0.00	0.01	0.01	0.06	0.15
133	2.65	0.06	0.05	0.23	0.40	0.73	0.89	0.00	0.01	0.01	0.06	0.15
134	2.51	0.03	0.05	0.22	0.39	0.72	0.88	0.00	0.00	0.01	0.03	0.08
135	...	0.03	...	...	...	...	...	0.00	0.00	0.01	0.03	0.08

**Test names are given in Table 2. Other abbreviations and definitions are given in Table 9.*

Table 13. Likelihood Ratios for Pathological and Normal Diagnoses as a Function of OMSE Score and Prevalence*

			Diagnosis, Likelihood Ratio									
			Pathological, % Prevalence					Normal, % Prevalence				
OMSE	PLR	NLR	2	10	20	50	75	2	10	20	50	75
19	42.0	...	0.46	0.82	0.91	0.98	0.99	...	...	...	...	...
20	51.0	0.59	0.51	0.85	0.93	0.98	0.99	0.01	0.06	0.13	0.37	0.64
21	57.0	0.49	0.54	0.86	0.93	0.98	0.99	0.01	0.05	0.11	0.33	0.60
22	61.0	0.43	0.55	0.87	0.94	0.98	0.99	0.01	0.05	0.10	0.30	0.56
23	30.5	0.39	0.38	0.77	0.88	0.97	0.99	0.01	0.04	0.09	0.28	0.54
24	21.7	0.40	0.31	0.71	0.84	0.96	0.98	0.01	0.04	0.09	0.29	0.55
25	22.7	0.36	0.32	0.72	0.85	0.96	0.99	0.01	0.04	0.08	0.26	0.52
26	17.3	0.33	0.26	0.66	0.81	0.95	0.98	0.01	0.04	0.08	0.25	0.50
27	17.3	0.32	0.26	0.66	0.81	0.95	0.98	0.01	0.03	0.07	0.24	0.49
28	14.4	0.32	0.23	0.62	0.78	0.94	0.98	0.01	0.03	0.07	0.24	0.49
29	12.3	0.29	0.20	0.58	0.76	0.92	0.97	0.01	0.03	0.07	0.22	0.47
30	9.63	0.28	0.16	0.52	0.71	0.91	0.97	0.01	0.03	0.07	0.22	0.46
31	6.67	0.25	0.12	0.43	0.63	0.87	0.95	0.01	0.03	0.06	0.20	0.43
32	5.79	0.23	0.11	0.39	0.59	0.85	0.95	0.00	0.02	0.05	0.19	0.41
33	5.38	0.22	0.10	0.37	0.57	0.84	0.94	0.00	0.02	0.05	0.18	0.40
34	4.52	0.17	0.08	0.33	0.53	0.82	0.93	0.00	0.02	0.04	0.15	0.34
35	3.54	0.06	0.07	0.28	0.47	0.78	0.91	0.00	0.01	0.01	0.06	0.15
36	2.61	0.01	0.05	0.22	0.39	0.72	0.89	0.00	0.00	0.00	0.01	0.03
37	...	0.02	...	...	...	...	...	0.00	0.00	0.00	0.02	0.06

Test names are given in Table 2. Other abbreviations and definitions are given in Table 9.

agnostic probabilities, the interpretation of a given test score must depend on the general environment of the patient. To make this estimation, one can use recent reviews of epidemiological studies.[6] For example, according to Siu,[5] the prevalence of dementia in nursing homes is about 50% (Table 9). If the tester wishes to interpret the score (score, 26) of a person who is in a nursing home as a probability of that score reflecting dementia (in which case 26 is considered with all the scores below it), the chances are 81% that the patient has dementia. If the score is to be interpreted as probabilities of reflecting normal functioning (and is considered with all the scores above it), the chance is 12% that the patient has dementia (Table 9). A score of 26, interpreted in the context of the base rate of the specific population, in this case the nursing home, is interpreted differently than if it is interpreted absolutely, or even if interpreted against another base rate. For example, the prevalence of dementia in ambulatory memory disorder clinics is suggested as about 75%. In that setting, a score of 26 probably indicates dementia with a 93% probability. Even if the score was interpreted as indicating normal performance (in which case it was considered with the scores above it), the patient still would have a 30% chance of having dementia.

Finally, the score can be interpreted as indicating dementia or normal functioning based on a cutoff. This approach is widely used but oversimplifies the situation (eg, by ignoring the prevalence of dementia in the given setting). According to this approach, a score of 26 should not be interpreted as indicating DAT (Table 3) because it is above the 23/24 cutoff generally used. However, if the cutoff is determined to differentiate normal performance from dementia in general (when all forms of dementia are included), the cutoff is positioned higher—28/29. A patient scoring 26 now would be considered as having dementia, because the score falls below the cutoff. Hence, the cutoff approach suggests that the patient has dementia but the dementia probably is not DAT.

In summary, a score of 26 on the MMSE is interpreted as high compared with a sample of patients who have DAT, and low when compared with patients who do not have dementia (based on z scores and percentiles). It cannot lead to a definite diagnosis in a setting in which the prevalence of dementia is 50% or lower, but should be interpreted as associated with dementia in a setting in which most of the patients have dementia. Finally, according to the cutoff approach, the score is not associated with DAT but is associated with dementia in general, suggesting consideration of other forms of dementia. These examples illustrate how one score may be interpreted in many different ways to provide answers to different clinical questions.

COMPARING SCORES ON DIFFERENT TESTS

When a patient is referred from another clinic that uses a different mental-status test than the one used by the accepting clinic, 2 approaches may be used. One is to translate the score on the other test into scale-free units such as z scores (Table 2) or percentile score (Tables 4 through 8). Another approach is to use a conversion formula. For example, assume your clinic uses MMSE. A patient was referred to you with a DRS score of 106, and you wish to know the equivalent of 106 on the MMSE. Convert the DRS score into a z score using the norms provided herein. If the comparison is with patients who have DAT, z is computed as 0, and performance would be considered average for such patients. If the comparison is with patients without dementia (Table 2), $z=-2.4$, well below average. Using percentiles, the corresponding percentile scores are 41 and 3

Table 14. Conversion Formulas to Derive Estimated Scores in 1 Test Based on Scores From Another Test*

Test	Formula	R^2	No. of Patients	RMSE
Based on the Entire Sample				
DRS	45.1+2.34×OMSE	.72	464	10.5
	45.5+3.01×MMSE	.69	466	11.1
	141.3−2.08×OMC	.55	464	13.4
	69.5+6.54×MSQ	.58	463	13.0
OMSE	−5.5+0.31×DRS	.72	464	3.8
	−.5+1.31×MMSE	.98	545	1.4
	41.9−1.02×KATZ	.78	544	4.4
	7.9+3.08×MSQ	.86	544	3.5
MMSE†	−3.1±0.23×DRS	.69	466	3.0
	.9+0.74×OMSE	.98	546	1.1
	32.0−0.75×OMC	.74	545	3.6
	7.0+2.26×MSQ	.81	545	3.1
OMC	42.8−0.27×DRS	.55	464	4.8
	35.0−0.76×OMSE	.78	544	3.8
	35.0−0.99×MMSE	.74	545	4.1
	30.1−2.54×MSQ	.78	543	3.8
MSQ	−3.1+0.09×DRS	.58	463	1.5
	−1.3+0.28×OMSE	.86	544	1.1
	−1.3+0.36×MMSE	.81	545	1.2
	10.7−3.1×OMC	.78	543	1.3
Based on Patients With DAT (Possible and Probable)				
OMC	33.4−0.83×MMSE	.74	163	3.5
	37.2−0.20×DRS	.50	123	4.4
	28.7−2.11×MSQ	.77	163	3.6
	33.0−0.64×OMSE	.79	163	3.2
MMSE	34.3−0.89×OMC	.74	163	3.7
DRS	147.1−2.54×OMC	.50	123	15.7
MSQ	11.6−0.37×OMC	.77	163	1.4
OMSE	45.32−1.23×OMC	.79	163	4.4
Based on Patients With VaD				
OMC	32.6−0.86×MMSE	.59	76	4.4
	35.6−0.20×DRS	.35	67	4.9
	28.2−2.26×MSQ	.66	76	4.0
	33.6−0.70×OMSE	.66	76	4.0
MMSE	31.2−0.68×OMC	.59	76	3.9
DRS	135.6−1.76×OMC	.35	67	14.6
MSQ	10.3−0.29×OMC	.66	76	1.4
OMSE	40.9−0.94×OMC	.66	76	4.6
Based on Nondemented Patients				
OMC	35.3−1.05×MMSE	.36	145	4.1
	45.4−0.30×DRS	.41	141	4.0
	30.6−2.77×MSQ	.46	145	3.8
	37.3−.87×OMSE	.43	145	3.9
MMSE	29.9−0.34×OMC	.36	145	2.3
DRS	140.5−1.37×OMC	.41	141	8.5
MSQ	9.9−0.17×OMC	.46	145	0.9
OMSE	39.1−0.50×OMC	.43	145	2.9

*RMSE indicates root mean square error. Other abbreviations and test names are given in Tables 1 and 2, respectively.
†Example.

(compared with patients who have DAT and who do not have dementia, respectively). These results suggest that the patient has DAT, because he or she performs at a level that is typical for patients who have DAT. The third possibility is to use the conversion formulas in Table 14: MMSE (estimated MMSE score=3.1(+0.23×DRS score). The estimated MMSE score would be −3.1(+0.23 ×106). The expected error associated with this formula (RMSE on the right side of the formulas in Table 14) is 3.0. In other words, based on the DRS score, the patient is predicted to have an MMSE score of 21±3.

COMMENT

The diagnosis of dementia relies on clinical evaluation, which includes assessment of mental status. Standardized neuropsychological tools are among the many sources of data clinicians use as supposedly objective indexes of mental status. It is clear, however, that the results of these tests may not be interpreted to the best advantage of the patients. In another article,[1] we compared 5 standardized tools for diagnosis of dementia, 3 of which are com-

Table 15. Conversion Formulas From Previous Studies*

Test	Formula	Reference
MMSE	28−0.717×IMC	Thal et al[7]†
IMC	39.1−1.39×MMSE	
IMC	33.51−0.972×MMSE	Salmon et al[8]‡
IMC	38.13−0.219×DRS	
MMSE	34.5−1.03×IMC	
MMSE	−12.72+0.31×DRS	
DRS	174.11−4.57×IMC	
DRS	41.53+3.26×MMSE	
MMSE	−10.0+0.29×DRS	Bobholz and Brandt[9]§
DRS	33.86+3.39×MMSE	

*Test names are given in Table 2. IMC indicates Information-Memory-Concentration Test (another version of the Blessed Test).
†N=40 patients with Alzheimer disease.
‡N=92 patients with probable Alzheimer disease.
§N=50 referred patients.

monly used. In this article, we provide various practical methods to interpret the test scores of these 5 tests.

The value of these norms as the basis for the different interpretations are the large sample size, the interrater validation of the diagnoses, and the longitudinal follow-up. Three types of interpretation methods are reported. The first set of methods allow comparison of a given test score with those obtained by several reference populations, such as patients with possible and probable DAT, patients with vascular dementia, and patients who eventually were diagnosed as not having dementia. This approach enables the clinician to determine if the patient being tested performed better or worse than patients in these reference populations. Under this heading, we include methods for deriving z scores and percentile scores.

A second set of methods allows for the translation of a test score directly to diagnosis. The cutoff approach is one such method. If the score obtained by the patient indicates worse performance than the cutoff score, the patient is diagnosed as having dementia. If the patient performs better than the cutoff score, the diagnosis excludes dementia. We do not recommend this approach, because using a single cutoff level fails to consider the prevalence of dementia in the population being tested. Furthermore, using cutoffs may leave the clinician with the illusion that diagnosis is certain.

We suggest a new approach that considers the prevalence of dementia in the patient's representative population. Each test score is associated with the probability or likelihood that the patient has dementia. Testers may use these probabilities directly or use them to create tailored cutoff values according to the guidelines we provided. Caution is required when the prevalence of dementia is high or low. Finally, we suggested several methods for the translation of a score in one test to its equivalent in another test. These last methods are not sufficiently precise to be applied to individual data but can be used to compare between groups of patients. Moreover, the conversion formulas are applicable only to a setting similar to ours (a memory disorder clinic) in which the prevalence rate of dementia is 75%.

In computing these norms for the posttest probabilities (Tables 9 through 13), we used patients with probable DAT as representative of patients with dementia. This results in better sensitivity and specificity of the tests than would be obtained if all types of dementia were pooled. In this group, the diagnosis of dementia is made with higher certainty than in the other types of dementia. Hence, PLR and NLR and prevalence were based on different types of dementia. The PLR and NLR were based on probable DAT and prevalence was based on all the dementias. Some users of the norms may find it unreasonable and may wish to generate their own probabilities based on the LNR and PNR that we report and the estimated likelihood of probable DAT in their setting.

The diagnosis of dementia is a clinical problem as the population ages. Standard neuropsychological tests often are used to assist in these diagnoses. The interpretation of the tests must be based on sufficiently large databases, and with the understanding of the meaning of an individual score depending on the question asked and the population to which the patient is referenced. We have addressed the diagnosis of general classifications of dementia. A similar approach is necessary as we identify dementia subtypes, even within a general classification.

Accepted for publication May 10, 1996.

This project was funded by a Rotman Research Fellowship, Toronto (Dr Meiran), research grants from the Alzheimer Society of Canada, the Ontario Mental Health Foundation, and the Medical Research Council of Canada (Dr Stuss), the Alzheimer Society of Ottawa—Carleton (infrastructure funds for the Memory Disorder Clinic at the Ottawa General Hospital), and the Ottawa (Ontario) General Hospital.

We are grateful to the patients of the clinic and their families, to the many staff members of the clinic who were necessary to the clinic's success in attracting patients, and to the neuropsychology interns and technicians who helped to test the patients.

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