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REVIEW ARTICLE

SCREENING FOR COGNITIVE IMPAIRMENT AFTER STROKE: A SYSTEMATIC REVIEW OF PSYCHOMETRIC PROPERTIES AND CLINICAL UTILITY

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Objective: **To systematically review the psychometric properties and clinical utility of cognitive screening tools post-stroke.**

Data sources: **EMBASE, CINAHL, MEDLINE, PsychInfo.**

Study selection: **Studies testing the accuracy of screening tools for cognitive impairment after stroke.**

Data extraction: **Data regarding the participants, selection criteria, criterion/reference measure, cut-off score, sensitivity, specificity and positive and negative predicted values for the selected tools were extracted. Tools with sensitivity ≥80% and specificity ≥60% were selected. Clinical utility was assessed using a previously validated tool and those scoring <6 were excluded.**

Data synthesis: **Twenty-one papers regarding 12 screening tools were selected. Only the Montreal Cognitive Assessment (MoCA) and Mini Mental State Examination (MMSE) met all psychometric and clinical utility criteria for any levels of cognitive impairment. However, the MMSE is most accurate to screen for dementia (cut-off score 23/24) and should only be used for this purpose. In addition, the following can be used to detect:**

- **Any impairment: Addenbrooke's Cognitive Examination-Revised (ACE-R), Barrow Neurological Institute Screen for Higher Cerebral Functions (BNIS) and Cognistat.**
- **Multiple-domain impairments: ACE-R, Telephone-MoCA or modified Telephone Interview for Cognitive Status (TICS).**
- **Dementia: TICS; Cambridge Cognitive Examination; Rotterdam-Cambridge Cognitive Examination; Informant Questionnaire for Cognitive Decline in the Elderly (IQCODE) and short-IQCODE. The IQCODE and short-IQCODE are useful when the patient is unable to respond and an informant's view is required.**

Conclusion: **The MoCA is the most valid and clinically feasible screening tool to identify stroke survivors with a wide range of cognitive impairments who warrant further assessment.**

Key words: stroke; cognition; screening; assessment.

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INTRODUCTION

Stroke affects 110,000 people every year in England, with 3 times as many survivors living with long-term disability (1). Approximately 80% of survivors experience acute cognitive impairment, which persists in 38–73% of cases (2, 3). Vascular dementia is also prevalent in approximately 10% of patients with first stroke, increasing to 30% after multiple events (4). Consideration of cognition is therefore a key component of rehabilitation and recovery, as impairments are associated with poor engagement in rehabilitation and outcomes including increased mortality (5, 6). As a result, effective processes to identify the nature and severity of cognitive impairments are a priority (7, 8).

Clinically it is important to be able to be able to detect post-stroke dementia, impairments of both single and multiple domains, and mild (or high-level) difficulties. Although rates have improved over the last decade, many stroke survivors are not screened for cognitive deficits (9) and a wide variety of tools are used in practice (10). This may be due to lack of time, training or availability of tools, as well as uncertainty about which tool to use (11). Thus, we systemically reviewed the psychometric properties and clinical utility (or feasibility) of cognitive screening tools for people with stroke, so that recommendations could be made about which tools are suitable for use in clinical practice.

METHODS

Search study and selection criteria

Databases (EMBASE, CINAHL, MEDLINE, PsychInfo) were searched from their inception until October 2013 using the following key words:

Assess* *or* screen* *or* tool *or* measure* *or* scale *or* test *or* index
And
Stroke *or* "cerebrovascular accident" *or* CVA
And
Cogniti* *or* dement* *or* memory *or* recall *or* attention *or* concentration *or* "executive function" *or* perception *or* planning *or* reasoning *or* language
And
Sensitiv* *or* specific* *or* "positive predictive value" *or* PPV *or* "negative predictive value" *or* NPV

All searches were limited to English language and adult humans.

The reference lists of the selected papers and previously published reviews were also searched. Titles, abstracts and full texts were

screened by 2 independent reviewers to identify screening tools for cognitive impairment after any type of stroke. Published articles reporting validation of a cognitive screening tool against a "gold-standard" criterion measure of cognitive functioning were included. This was defined as a neuropsychological assessment of 3 or more elements of cognitive function from: orientation; attention and concentration; memory; language; executive function and visuo-perceptual function. For tools to detect possible dementia, a clinical diagnosis was accepted. Comparison between studies was facilitated by excluding studies involving:

- another screening tool as the criterion/reference measure;
- screening tools that covered 3 or fewer of the domains outlined above;
- the psychometric properties of a language translation of a tool;
- less than 50% of participants with stroke/transient ischaemic attack, or data from these participants could not be extracted;
- abstracts or conference papers from which sensitivity or specificity values could not be extracted.

As cognition covers many impairments of varied severity, screening tools aim to detect a varied range of deficits. To aid analysis of how the tools could, or should, be used in clinical practice, we pragmatically assessed the ability of the tools to detect impairments at 3 levels; post-stroke dementia, multi-domain impairments, and "any degree of cognitive impairment" (including mild and single-domain impairments).

Data extraction and analysis

Data regarding the participants, selection criteria, criterion/reference measure, cut-off score, sensitivity, specificity and positive and negative predicted values for the selected tools were extracted independently by the authors. Agreement of final data was reached by consensus, and a third party was available to arbitrate in cases of disagreement. Tools with sensitivity $\geq 80\%$ and specificity $\geq 60\%$ for at least one cut-off score were considered sufficiently accurate and were selected. Cut-off scores that did not meet these criteria were excluded. Different criteria were used for sensitivity and specificity because they are widely used in clinical practice and in recognition of the trade-off between them; the consequences of failing to identify an individual with difficulties are greater than the costs of further evaluation of those who may not require treatment (12). Studies were then classified into those aiming to detect possible post-stroke dementia, multi-domain impairments or any degree of cognitive impairment in any domain (referred to as "any impairment").

Screening tools meeting the sensitivity and specificity criteria were then assessed for clinical utility (the feasibility of using a tool in clinical practice) using data from the original articles or instruction manuals. Marketing material was surveyed to ascertain costs and the tools' authors contacted if necessary. Clinical utility was assessed using a previously published tool (13), which was adapted by a consultation group of occupational therapists and clinical psychologists working in stroke rehabilitation to reflect their priorities. Their views are summarized as follows: medical staff or occupational therapists usually undertake initial cognitive screening; thus it is important that screening tools can be employed by any member of the multidisciplinary team without specialist training. Equally, brevity is important to minimize demands on staff time and the burden on patients. Finally, tools that are freely available or incurred minimal costs would be preferred over a more expensive measure if it performed equally well in terms of psychometrics. These criteria were transformed into scores as follows:

- time to administer and score the measure: 2 = ≤ 10 min; 1 = 11–20 min; 0 = >20 min;
- initial costs for purchase of the measure (e.g. starter kit including manual): 2 = freely available; 1 = cost of < £100; 0 = cost of ≥ £100 or unavailable;
- additional cost per record form: 1 = no additional costs; 0 = additional cost or unavailable;
- need for specialist training to administer and score the measure: 1 = minimal training required; 0 = specialist training required.

Scores were summed to give a maximum of 6 points; higher scores indicate greater clinical utility. Tools scoring < 6 were rejected at this stage.

RESULTS

Thirty screening tools were identified. Eighteen tools did not meet the selection criteria: 8 were not developed to screen for overall cognitive impairment, or did not cover at least 3 domains (4 A Test (14), Abbreviated Mental Test-4 item (15), Clock Drawing Test (16), Kaufman Short Neuropsychological Assessment Procedure Impairment Index (17), Mattis Dementia Rating Scale – Initiation-Perseveration subscale (18), Preliminary Neuropsychological Battery (19), Screening Instrument for Neuropsychological Impairments in Stroke (20), Weigl Colour-Form Sorting Test (21)). Four tools had only been validated against other screening tools (Addenbrooke's Cognitive Examination-Revised 9-item (22); Intelligent Cognitive Assessment System (23); National Institute of Neurological Disorders and Stroke-Canadian Stroke Network 'short MoCA' (24); new short Montreal Cognitive Assessment (25)) and a further 6 did not reach the sensitivity and specificity criteria at any cut-off scores (Abbreviated Mental Test (26), COG-4 (27), Middlesex Elderly Assessment of Mental State (28), Modified Mini Mental State (29), Standardised-Mini Mental State Examination (30), Telephone-Montreal Cognitive Assessment-short (31)).

Twenty-one selected papers assessed the 12 remaining screening tools involving 2,148 stroke survivors. These are described in Table I and the populations tested are detailed in Table II. Most studies primarily included participants with stroke or transient ischaemic attack, whilst others were more specific and only included people with subarachnoid haemorrhage (32) or lacunar infarcts (33, 34). Most studies recruited from acute in-patient settings (32–42), although some recruited rehabilitation in-patients (43–45) and out-patients attending clinics or day hospitals (46–48). Most assessments were made in the acute stage (within 1 month) of stroke (32, 33, 36–39, 41) or sub-acute stage (1–6 months) (32, 34, 35, 42, 43, 45, 48). Four papers considered long-term cognitive impairment (more than 6 months) (31, 32, 46, 49). Two further studies assessed participants at 3–9 months post-stroke (50, 51). Several criterion measures were used as the reference gold-standard. All tools screening for "any impairment" or multi-domain impairments used a neuropsychological assessment (31–33, 36–38, 40–44, 46, 48, 49), while dementia screening tools were compared with a clinical diagnosis based on neuropsychological and clinical assessment, discussion with an informant and Diagnostic and Statistical Manual (DSM) criteria (34, 35, 39, 41, 45, 47, 49–51).

Five tools met the sensitivity and specificity criteria to accurately screen for "any impairment": Addenbrooke's Cognitive Examination-Revised (ACE-R) (52), Barrow Neurological Institute Screen for Higher Cerebral Functions (BNIS) (53, 54), Cognistat (55), Mini Mental State Examination (MMSE) (56) and the Montreal Cognitive Assessment (MoCA) (57). The sensitivity and specificity for each cut-off score are detailed in Table III and the tools are briefly described below. All tools

Table I. *Brief description of each identified measure meeting psychometric criteria in at least one validation study*

Measure	Brief description of measure	Time to administer, min	Training required?	Initial costs	Recurring costs	Clinical utility score/6
ACE-R (52)	26 clinician-rated pencil-and-paper and verbal tasks assess orientation and attention, memory, language, verbal fluency and visuospatial skills. Correct responses totalled, max.=100 points. Incorporates the MMSE.	15	Minimal	£48.22 for MMSE manual with pocket norms	84p per MMSE administration	3
BNIS (53, 54)	Clinicians assess alertness, basic language and cooperation If intact, 27 pencil-and-paper and verbal items assess orientation and attention, memory, awareness, language, visuospatial problem-solving and affect. Scores are totalled, max.=50 points.	15	Minimal for experienced clinician	Unavailable commercially	Unavailable commercially	1
CAMCOG (59)	Incorporates part of the Cambridge Examination for Mental Disorders of the Elderly and MMSE; 67 clinician-administered pencil-and-paper and verbal items assess orientation and attention, language, memory, praxis, calculation, abstraction and perception. 48 items given 1 point for a correct response, 11 items scored on a 3-point scale. 8 items are not scored. Points are totalled, max.=107.	20–30	Minimal for administration, psychological/ medical training for interpretation	Unavailable	Unavailable	0
Cognistat (55) (formerly the Neurobehavioral Cognitive Status Examination)	Clinician-administered verbal and pencil-and-paper items covering consciousness orientation, attention, language, spatial skills, memory, constructions and reasoning. Each domain has a screening question; if failed easier items are completed. If passed, the test proceeds to the next domain. Scores provide a profile for each domain, graded as average, mild, moderate or severe.	15–20	Minimal for administration Psychological or medical training for interpretation	£355.12 for starter kit + postage	£9.26 per record form + postage	0
IQCODE (60)	Informant-completed items rate change in orientation and attention, memory and executive function over time in 26 everyday situations on a 5-point Likert scale ("much improved" to "much worse"). Scores averaged, max.=5.	10–15	Minimal	Freely available	Freely available	5
Short IQCODE (61)	Short form of the IQCODE (see above) containing 16 items on orientation, memory, decision-making and reasoning.	10–12	Minimal	Freely available	Freely available	5
MMSE (56)	Clinician-administered verbal and pencil-and-paper items covering orientation and attention, memory, language and praxis. Correct responses are summed, max.=30 points.	10	Minimal	£48.22 for manual with pocket norms	84p per administration	4
MoCA (57)	Clinician-administered verbal questions and pencil and paper tasks covering orientation and attention, memory, language, visuospatial skills, executive function, verbal fluency and abstract thought. Correct responses plus an extra point for ≤12 years education are summed, max.=30. Alternate versions available for repeated testing.	10	Minimal	Freely available	Freely available	6
R-CAMCOG (50)	Revised version of the CAMCOG (incorporating MMSE). 25-items (in 6 subscales) Clinician-administered verbal test plus 1 written task on orientation and attention, perception and abstraction. Correct responses are summed, max.=49.	10	Minimal	Unavailable as the CamCog is needed to use	CAMCOG unavailable	3
TICS (62)	11 telephone-administered verbal items on orientation and attention, memory, language, conceptual knowledge and praxis. Correct responses are summed, max.=41 points.	5–10	Trained healthcare professional	£58.73 for introductory kit	84p per administration	3
TICSm (58)	Modified version of the TICS (see above); 13 items test orientation and attention, memory, repetition, conceptual knowledge and praxis. Scores are summed, max.=39 points.	5–10	Trained healthcare professional	£58.73 for introductory kit	84p per administration	3
T-MoCA (31)	Telephone-administered version of the MoCA (see above). Correct responses for orientation, memory, executive function and attention are summed, max.=22 points.	5–10	Minimal	Freely available	Freely available	6

All costs are calculated as of September 2013. ACE-R: Addenbrooke's Cognitive Examination-Revised; BNIS: Barrow Neurological Institute Screen for Higher Cerebral Functions; (R-)CAMCOG: (Rotterdam) Cambridge Cognitive Examination; IQCODE: Informant Questionnaire for Cognitive Decline in the Elderly; MMSE: Mini Mental State Examination; (T-)MoCA: (Telephone) Montreal Cognitive Assessment; TICS(m): (Modified) Telephone Interview for Cognitive Status; max.: maximum.

Table II. *Descriptions of the selected papers*

Study	Participants with stroke	Exclusion criteria	Tool	Criterion measure	Time post-stroke	Cut-off score	Sens %	Spec %	PPV %	NPV %
Blake et al., 2002 (40)	112 in-patients, age 71 (SD 12) years	Unconscious on admission, unable to cooperate, blind, deaf	MMSE	Neuropsychological assessment battery, any impairment	In-patients	23/24	62	88		
Boosman et al., 2013 (48)	26 out-patients, aged >55 years	Stroke >12 months before assessment, poor functional outcome (Barthel score <19/20 points), non-Dutch speaking	BNIS	Neuropsychological assessment – any cognitive impairment	15 weeks (mean)	39/40	77	92		
						40/41	92	85		
						41/42	92	60		
						42/43	92	62		
						43/44	92	62		
						44/45	92	31		
						45/46	100	31		
						46/47	100	31		
						47/48	100	8		
						48/49	100	0		
						49/50	100	0		
	28 out-patients, aged <56 years					39/40	30	94	93	
						40/41	30	89		
						41/42	40	89		
						42/43	50	83		
						43/44	50	61		
						44/45	50	56		
						45/46	70	39		
						46/47	80	39		
						47/48	100	17		
						48/49	100	17		
						49/50	100	11		
Bour et al., 2010 (41)	194 consecutive hospital admissions, mean age=68 (SD 13) years	Previous stroke, <40 years, inadequate Dutch, MMSE <16, aphasia, pre-stroke dementia or co-morbid neurological psychiatric disorders	MMSE	Neuropsychological assessment battery – any cognitive impairment	<1 month post-stroke	27/28	72	71	93	
				impairment in 2+ domains		27/28	80	70	86	
				impairment in 4+ domains		26/27	82	75	72	
				Clinician diagnosis of dementia based on DSM-IV criteria		23/24	96	83	41	
Cumming et al., 2013 (42)	60 stroke admissions followed-up at 3 months, mean age=72 (SD 14) years	<18 years, unconscious on admission, required interpreter, major visual, hearing or language impairments	MMSE	Neuropsychological assessment battery – any cognitive impairment	Mean 98 days (SD 12) post-stroke	24/25	54	81		
						25/26	64	81		
						26/27	82	76	86	70
						27/28	92	52		
						28/29	100	33		
			MoCA			21/22	77	76		
						22/23	80	71		
						23/24	92	67	84	82
						24/25	97	52		
						25/26	100	43		
de Koning, 2000 (50)	284 patients from stroke registry, age=69 (SD 8) years	<55 years, aphasia, severe psychiatric problems, semi-consciousness, insufficient Dutch	R-CAMCOG	Diagnosis of DSM-III-R dementia (neuropsychological, clinical and informant assessment)	3–9 months post-stroke	32/33	91	90		
			CAMCOG			76/77	91	88		
de Koning et al., 2005 (51)	121 consecutive stroke/TIAs in last 3–9 months, age=70 (SD 9) years	<55 years, aphasia, severe psychiatric problems, semi-consciousness, insufficient Dutch	R-CAMCOG	Diagnosis of DSM-IV dementia (neuropsychological, clinical and informant assessment)	3–9 months post-stroke	33/34	66	94	82	87
						36/37	83	78	76	92

Table II. *Contd.*

Study	Participants with stroke	Exclusion criteria	Tool	Criterion measure	Time post-stroke	Cut-off score	Sens %	Spec %	PPV %	NPV %
Desmond et al., 1994 (47)	36 out-patient strokes, age=72±9 years	<60 years, aphasia, semi-consciousness, not English or Spanish speaker	TICS	Diagnosis of dementia (neuropsychological and functional assessment)	Out-patients	24/25	100	83		
			MMSE			23/24	83	87		
Dong et al., 2010 (39)	100 acute stroke/TIA patients, age=61 (±11.3) years	<21 years, medically unstable, severe physical disability, aphasia, major psychiatric illness, pre-stroke dementia	MMSE	DSM-IV dementia diagnosis (neuropsychological and clinical assessment)	4.2±2.4 days	22/23	77	91	91	79
						23/24	84	86	87	83
						24/25	86	82	84	84
						25/26	90	75	80	88
						26/27	94	61	73	90
			MoCA			19/20	77	89	89	78
						20/21	84	84	85	83
						21/22	90	77	81	88
						22/23	92	68	76	88
						23/24	95	61	73	92
Fure et al., 2006 (33)	71 acute in-patients, age=66 (SD 9) years	Co-morbid cardio-vascular disease	MMSE	Screening evaluation – any cognitive impairment	Acute in-patients	24/25	19	92	78	45
						26/27	28	85	71	43
						28/29	69	65	74	61
Godefroy et al., 2011 (38)	95 acute in-patients, age=68 (±14) years	>3 weeks post-stroke, severe neurological co-morbidity, illiteracy, learning disability, previous severe traumatic brain injury, schizophrenia, psychosis, primary language not French	MMSE	Comprehensive neuropsychological assessment (except if MMSE <23) – impairment in 2 or more domains	6.6±3.5 days (screening) 24.1±6.4 days (full assessment)	20/21	45	100	100	47
						21/22	56	100	100	53
						22/23	63	100	100	56
						23/24	64	97	98	57
						24/25	70	94	96	60
						25/26	77	87	92	64
						26/27	80	77	88	65
						27/28	86	61	82	68
						28/29	95	39	76	80
						29/30	100	10	70	100
						30/31	100	0	67	100
			MoCA			15/16	44	100	100	46
						16/17	55	100	100	52
						17/18	61	100	100	55
						18/19	63	97	98	56
						19/20	69	94	96	59
						20/21	72	90	94	61
						21/22	75	87	92	63
						22/23	78	77	88	63
						23/24	88	71	86	73
						24/25	92	58	82	78
						25/26	94	35	75	73
						26/27	97	19	71	75
						27/28	98	16	71	83
						28/29	100	13	70	100
						29/30	100	3	68	100
						30/31	100	0	67	100
Grace et al., 1995 (44)	70 rehabilitation in-patients, age =75 (SD 8) years	None reported	MMSE	Neuropsychological assessment – impairment in 2+ domains	In-patients	24/25	44	84		
						26/27	81	45		
Morris et al., 2012 (37)	61 acute in-patients, age=76 (IQR 67–83)	Psychiatric history, blind, deaf, too ill/ drowsy, no English language, aphasia	MMSE	Neuropsychological assessment – any cognitive impairment	18 (IQR=9–48.8) days	23/24	55	60	88	21
						26/27	80	20	84	16
			ACE-R			74/75	59	40	83	16
						81/82	80	40	87	28
						87/88	90	20	85	28
Nøkleby et al., 2008 (43)	49 rehabilitation in-patients, age=62 (54–77) years	<19 years	Cognistat – total score	Basic neuropsychological assessment – any cognitive impairment	38 (IQR=17–89) days	8/9	81	67		
			Cognistat – composite			59/60	59	67		
						64/65	82	50		

Table II. *Contd.*

Study	Participants with stroke	Exclusion criteria	Tool	Criterion measure	Time post-stroke	Cut-off score	Sens %	Spec %	PPV %	NPV %
Nys et al., 2005 (36)	34 consecutive admissions, age = 64.7 ± 12 years	Severe disability, non-native speaker, aphasia, impaired consciousness, blind	MMSE	Neuropsychological assessment – any cognitive impairment	6.5 ± 2.9 days	22/23	30	100		
						23/24	35	70		
						24/25	57	60		
						25/26	70	40		
						26/27	96	40		
						27/28	100	40		
						28/29	100	30		
Pendlebury et al., 2012 (46)	91 clinic attendees, age = 73 (SD 12) years	Institutionalization, severe hearing/ visual impairment, inability to use right arm, dysphasia, poor English language, acute illness	MoCA	Neuropsychological assessment of mild cognitive impairment – any cognitive impairment	Assessment completed at 1- or 5-year follow-up	22/23	49	90	79	70
						23/24	59	85	74	73
						24/25	77	83	77	83
						25/26	87	63	64	87
			ACE-R			87/88	56	100	100	75
						89/90	67	98	96	80
						91/92	72	79	72	79
						93/94	83	73	70	85
			MMSE			25/26	36	92	78	66
						26/27	49	90	79	70
						27/28	64	88	81	77
						28/29	77	81	75	82
			MoCA	Neuropsychological assessment of mild cognitive impairment = impairment in 2+ domains		24/25	89	69	44	96
			ACE-R			91/92	88	69	42	96
			MMSE			27/28	79	78	48	93
Pendlebury et al., 2013 (31)	91 consecutive community-dwelling patients with TIA/stroke, age = 73 (SD 12) years		T-MoCA	Neuropsychological assessment – any cognitive impairment	1- and 5-year follow-ups	15/16	44	78	57	68
						16/17	63	76	63	76
						17/18	81	59	56	83
						18/19	89	46	52	86
				Neuropsychological assessment – impairment in 2+ domains		15/16	58	75	33	89
						16/17	83	70	37	95
						17/18	100	52	31	100
						18/19	100	39	26	100
			TICSm	Neuropsychological assessment – any cognitive impairment		21/22	67	78	67	78
						22/23	74	73	65	81
						23/24	78	61	57	81
						24/25	85	56	56	85
				Neuropsychological assessment – impairment in 2+ domains		21/22	75	68	33	93
						22/23	83	63	32	95
						23/24	83	52	27	94
						24/25	92	46	27	96
Srikanth et al., 2006 (49)	79 consecutive strokes	Aphasia, blind, deaf, dementia (for "any cognitive impairment")	Short IQCODE	Neuropsychological battery – any cognitive impairment		3.2/3.3	41	67	46	62
				DSM-IV dementia		3.2/3.3	88	63	21	98
Tang et al., 2003 (35)	189 consecutive strokes (age = 68 ± 12) and their carers, 3-months post-stroke	<18 years, stroke >7 days pre-admission, non-Cantonese speaking, no carer, co- or pre-morbid neurological conditions	IQCODE	Psychiatric diagnosis of DSM-IV dementia	3 months post-stroke	3.40/3.41	88	75	33	98
Tang et al., 2005 (34)	83 mild strokes, age = 73 ± 10 years	As above – except carer availability	MMSE	Psychiatric diagnosis of DSM-IV dementia	3 months post-stroke	18/19	93	80	36	98
Tatemichi et al., 1991 (45)	202 in-patient strokes	Unknown	MMSE	Diagnosis of dementia	3 months post-stroke	23/24	84	76	47	6

Table II. *Contd.*

Study	Participants with stroke	Exclusion criteria	Tool	Criterion measure	Time post-stroke	Cut-off score	Sens %	Spec %	PPV %	NPV %
Wong et al., 2013 (32)	72 subarachnoid haemorrhages at 2–4 weeks. Age = 58, IQR = 49–66 years. 80 chronic strokes. Age = 52, IQR 47–61) years	< 21 or > 75 years, not Cantonese-speaking, previous neurological disease, unable to obey commands	MMSE	Neuropsychological assessment battery – impairment in 2 or more domains	2–4 weeks post-stroke	23/24	75	90	60	95
					1 year post-stroke	23/24	58	84	39	92
			MoCA		2–4 weeks post-stroke	17/18	75	95	75	95
					1 year post-stroke	21/22	100	75	41	100

ACE-R: Addenbrooke's Cognitive Examination-Revised; BNIS: Barrow Neurological Institute Screen for Higher Cerebral Functions; CAMCOG: Cambridge Cognitive Examination; DSM: Diagnostic and Statistical Manual; IQCODE: Informant Questionnaire for Cognitive Decline in the Elderly; MEAMS: Middlesex Elderly Assessment of Mental State; MMSE:Mini Mental State Examination; (T-)MoCA: (Telephone)Montreal Cognitive Assessment; R-CAMCOG: Rotterdam-CAMCOG; TICS: Telephone Interview for Cognitive Status; TICSm: Modified Telephone Interview for Cognitive Status; SD: standard deviation; IQR: interquartile range; TIA: transient ischaemic attack; Sens: sensitivity; Spec: Specificity; PPV: positive predictive value; NPV: negative predictive value.

Table III. *Sensitivity and specificity of the selected tools to detect "any impairment", multi-domain impairments and dementia. Only cut-off scores with sensitivity ≥80% and specificity ≥60% are presented. Those meeting the criteria in all studies are highlighted in bold*

Screening instrument	Degree of impairment	Cut-off score	Sensitivity, %	Specificity, %
ACE-R (52)	Any impairment	93/94	**83 (46)**	**73 (46)**
	Multi-domain	91/92	**88 (46)**	**69 (46)**
BNIS (53, 54)	Any impairment	40/41	30–92 (48)	85–89 (48)
		41/42	30–92 (48)	60–89 (48)
		42/43	50–92 (48)	62–83 (48)
		43/44	50–92 (48)	61–62 (48)
CAMCOG (59)	Dementia	76/77	**91 (50)**	**88 (50)**
Cognistat (55)	Any impairment	8/9	**81 (43)**	**67 (43)**
IQCODE (60)	Dementia	3.40/3.41	**88 (35)**	**75 (35)**
MMSE (56)	Any impairment	26/27	28–96 (33, 36, 37, 42, 46)	20–90 (33, 36, 37, 42, 46)
	Multi-domain	26/27	80–81 (38, 44)	45–77 (38, 44)
		27/28	79–86 (38, 41, 46)	61–78 (38, 41, 46)
	Dementia	18/19	**93 (34)**	**80 (34)**
		23/24	**83–96 (39, 41, 45, 47)**	**76–87 (39, 41, 45, 47)**
		24/25	**86 (39)**	**82 (39)**
		25/26	**90 (39)**	**75 (39)**
		26/27	**94 (39)**	**61 (39)**
MoCA (57)	Any impairment	22/23	49–80 (42, 46)	71–90 (42, 46)
		23/24	59–92 (42, 46)	67–85 (42, 46)
		25/26	87–100 (42, 46)	43–63 (42, 46)
	Multi-domain	21/22	**75–100 (32, 38)**	**75–87 (32, 38)**
		23/24	**88 (38)**	**71 (38)**
		24/25	89–92 (38, 46)	58–69 (38, 46)
	Dementia	20/21	**84 (39)**	**84 (39)**
		21/22	**90 (39)**	**77 (39)**
		22/23	**92 (39)**	**68 (39)**
		23/24	**95 (39)**	**61 (39)**
R-CAMCOG (50)	Dementia	32/33	**91 (50)**	**90 (50)**
		36/37	**83 (51)**	**78 (51)**
Short IQCODE (61)	Dementia	3.29/3.30	**88 (49)**	**63 (49)**
TICS (62)	Dementia	24/25	**100 (47)**	**83 (47)**
TICSm (58)	Multi-domain	22/23	**83 (31)**	**63 (31)**
T-MoCA (31)	Multi-domain	16/17	**83 (31)**	**70 (31)**

ACE-R: Addenbrooke's Cognitive Examination-Revised; BNIS: Barrow Neurological Institute Screen for Higher Cerebral Functions; MMSE: Mini Mental State Examination; MoCA: Montreal Cognitive Assessment; TICSm: Telephone Interview for Cognitive Status-modified; T-MoCA: Telephone Montreal Cognitive Assessment; CAMCOG: Cambridge Cognitive Examination; IQCODE: Informant Questionnaire for Cognitive Decline in the Elderly; R-CAMCOG: Rotterdam-Cambridge Cognitive Examination; Short IQCODE: Short Informant Questionnaire for Cognitive Decline in the Elderly; TICS: Telephone Interview for Cognitive Status.

were clinician-administered. Most contain a mixture of verbal questions/problems and patient-completed pencil-and-paper tasks, some with observations of consciousness, affect and awareness. Most frequently, "correct" responses were summated to give a total score. An exception was the Cognistat (55), which was divided into cognitive domains, each beginning with a screening question, which if passed indicates intact functioning (so no further testing is needed). If failed, the other items are completed to devise a cognitive profile for the individual, however reported sensitivity and specificity is based on the total number of intact domains. Only the ACE-R (52), Cognistat (55) and MoCA (57) screen for difficulties in all the identified domains; the others (53, 54, 56) omitted executive functioning.

Five tools met the sensitivity and specificity criteria to detect multi-domain impairments (Table III): ACE-R (52), MMSE (56), MoCA (57), modified Telephone Interview for Cognitive Status (mTICS) (58) and Telephone Montreal Cognitive Assessment (T-MoCA) (31). All are clinician-administered using verbal questions/problems and pencil-and-paper tasks, except the telephone-delivered tests, which contain only verbal questioning. Only the ACE-R (52) and MoCA (57) screen for difficulties in all the cognitive domains; the MMSE (56) excludes executive function, whilst the T-MoCA (31) excludes visuospatial functioning and language, and the mTICS (58) omits all 3. All the tools award points for correct responses and summate the scores.

Seven tools had data suggesting that they could screen for dementia with sufficient accuracy to meet our criteria: Cambridge Cognitive Examination (CamCog) (59), Informant Questionnaire for Cognitive Decline in the Elderly (IQCODE) (60), Short Informant Questionnaire for Cognitive Decline in the Elderly (S-IQCODE) (61), MMSE (56), MoCA (57), Rotterdam-Cambridge Cognitive Examination (R-CamCog) (50) and Telephone Interview for Cognitive Status (TICS) (62). All are clinician-administered using verbal questioning and pencil-and-paper tasks except the R-CamCog (50) and TICS (62), which have only verbal items. Both versions of the IQCODE (60, 61) require a friend or relative to rate change in cognitive functioning over the previous 10 years on a 5-point Likert scale from "much improved" to "much worse". Then mean item scores are calculated. Only the MoCA (57) assesses all the cognitive domains; the CamCog (59) and MMSE (56) omit executive functioning and R-CamCog (50) additionally excludes language. Both forms of the IQCODE (60, 61) exclude language and visuospatial function, while the TICS (62) includes language, but omits visuospatial and executive function.

Having selected screening tools with data demonstrating they could accurately screen for cognitive impairments, the optimal cut-off scores to detect the possibility of "any impairment", multi-domain impairments or dementia were explored (Table III). Multiple cut-off scores for most tools relied on a single validation study, thus preventing identification of optimal scores. The MoCA (57) and MMSE (56) had received more attention. All studies found the MMSE (56) could accurately detect the possibility of dementia with a score of 23/24 (39, 41, 45, 47), suggesting that this is a robust cut-off level. Three studies showed that a score of 27/28 on the MMSE (56) almost met the criteria to detect the possibility of multi-domain impairment (41, 44, 46); however, results to detect "any impairment" were variable (33, 36, 37, 42, 46). In contrast, the MoCA (57) demonstrated a clear trade-off between sensitivity and specificity as the cut-off scores increased when used to identify "any impairment", multi-domain impairments and dementia. However, there was insufficient data to identify an optimal cut-off score for any category of impairment.

The 12 selected screening tools were then assessed for clinical utility (Table I). Only the MoCA (original and telephone versions (31, 57) scored full marks (6/6) and could be recommended for clinical use. The other tools scored between 0 and 5 points. Most could be administered quickly (in 10 min or less) (31, 50, 56–58, 62). Three were unavailable (50, 53, 54, 59). Only 2 were free to use (31, 57, 60, 61), while the others required initial purchase plus costs for each administration.

DISCUSSION

Our extensive search strategies identified a wide range of tools to screen for cognitive impairments and dementia post-stroke; however, only the MoCA (57) and MMSE (56) had data to show they could accurately screen impairments at all levels of severity and were clinically feasible. If the aim of screening is solely to detect the possibility of vascular dementia, the best option is the MMSE (56) using a cut-off score of 23/24; however, sensitivity and specificity to detect milder impairments are variable and it is ineffective for this purpose. The MoCA (57) can identify screen for all levels of impairment using lower cut-off scores to detect greater severity of difficulty. Of the other tools, there are data to show that the following can be used in clinical practice to screen accurately for:

- any impairment: the BNIS (53, 54), ACE-R (52) and Cognistat (55);
- multi-domain impairments: the ACE-R (52), Telephone-MoCA (31) and mTICS (58);
- dementia: the CamCog (59), IQCODE (60), short IQCODE (61), R-CamCog (50) and TICS (62).

However, only the (original and telephone) MoCA (31, 57)~ met all clinical utility criteria: They are freely available and can be quickly administered with minimal training.

To the authors' knowledge, this is the first systematic review of cognitive screening tools after stroke, and particularly the first to consider the clinical utility of tools with a view to implementation in clinical practice by the multi-disciplinary team. Early rehabilitation of cognitive problems is increasingly important with the rise of community-based rehabilitation services resulting in shorter hospital stays (63). Milder cognitive impairments may not become apparent until after discharge, when complex tasks, such as returning to household responsibilities, employment and driving are attempted. By this time, rehabilitation has often completed and it can be difficult to re-access services. A brief, psychometrically robust screening

measure to detect the possibility of problems at all levels and all domains, in the acute stage is therefore a priority.

We found that, although many screening tools are available and widely used for stroke (10), most were developed to screen for global cognitive decline in elderly people and subsequently applied to stroke. Consequently, they do not include all the cognitive domains affected by stroke, which explains why many tools are unable to detect milder impairments. Executive dysfunction is particularly neglected, which is surprising, as it is a key feature of other degenerative cognitive illnesses such as Alzheimer's disease (64). The superior sensitivity of the MoCA to milder cognitive deficits after stroke, compared with other tools such as the MMSE, has been well-documented (39, 65, 66) and is probably attributable to its initial development as a screen for mild cognitive impairment (although not specifically for stroke) and its consideration of executive function. Like any systematic review, our results are dependent on the data available, and several promising tools could only be recommended for specific domains because they had not been tested to detect all domains, rather than they had been tested and found to be ineffective. For example, the ACE-R has not been tested for the ability to detect dementia. Future publications assessing such tools' ability to detect a wider range of cognitive impairments may mean that our recommendations would need to be updated.

Assessment of cognitive impairment following stroke is complicated by additional stroke-related impairments, such as visual disturbance, weakness of the dominant hand and dysphasia, which limit pencil-and-paper tasks, comprehension and responses to verbal tasks. In addition, fatigue, pain and mood disturbance are common post-stroke (67) and may result in false-positive cases for cognition because of their effects on motivation and concentration. Consequently, recommended cut-off scores may be higher for stroke than in non-neurological populations, and careful interpretation of test scores is required to take these issues into account.

We reviewed only studies that used a neuropsychological assessment as a "gold-standard" criterion/ reference measure to facilitate comparison between tools. This excluded several shorter versions of existing tools, which were validated against the original tool (22, 25) but show promise as very brief initial screens. For example, 2 shorter versions of the MoCA performed well psychometrically compared with the full-length assessment (25). However, shorter versions have not always proved effective; a brief-ACE-R performed well against the original, but no better than chance compared with a neuropsychological battery (22). Therefore shortened versions of screening tools need to be validated against a gold-standard criterion measure before use in preference to the original tool.

The selected studies involved participants at varied times and settings post-stroke, and most excluded those unable to complete the assessments or with confounding conditions. This strategy boosts completion rates, but limits representativeness of the results and thus information regarding implementation. Three studies have explored this issue (65, 68, 69). They found that approximately 85% of community-dwelling or post-acute (> 3 months) stroke survivors could complete the tools (65, 69). Of those who could not be tested, aphasia accounted for 24%; dementia (15%) and inability to use the dominant hand (9%) (65). Impaired consciousness was also a barrier in the acute setting (68), although overall completion rates were similar (88%).

A limitation of this review is that the quality of the analysis is dependent on the articles selected. As there are no widely accepted methods to assess the quality of screening tools, and because we sought results that were representative of clinical practice, we used an inclusive strategy by including all papers addressing the psychometrics of cognitive screening tools, so methodological shortcomings may have affected the results. For example, in some studies, the screening and reference assessments were not administered concurrently (31, 38, 40), so cognitive function could have substantially recovered in the interval period, thus affecting the sensitivity and specificity. Nor did we specify the time since stroke, which may also have contributed to the variability in effective cut-off scores. Furthermore, although our sensitivity and specificity criteria reflect clinical priorities, their choice was relatively arbitrary and alternative criteria may produce other results. Finally, the review is also limited by the completeness of the evidence. There are many areas in which the research is incomplete; thus we do not claim that this is a definitive review, but an assessment of the current state-of the-evidence to aid clinical decision-making. As with all systematic reviews, future publications may alter the results and the recommendations made.

In conclusion, this study reviewed the psychometric properties and clinical utility of cognitive screening tools after stroke. Only the MoCA (57) met our criteria for an accurate, quick, easy-to-use, comprehensive brief cognitive screening tool. The telephone-delivered MoCA (31) detects the possibility of multi-domain impairment and may be useful when face-to-face testing is not possible. The MMSE (56) can detect the possibility of dementia, but incurs a cost. The IQCODE (60) and short-IQCODE (61) can be used when an informant's view is required, but should only be used when objective testing is not possible, or as a supplement, as they consider fewer cognitive domains. The ACE-R (52) can detect "any impairment" and multi-domain impairments, but has not been tested for detecting dementia.

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