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Clinical short communication

Additional Queen Square (QS) screening items improve the test accuracy of the Montreal Cognitive Assessment (MoCA) after acute stroke

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ABSTRACT

Background: The Montreal Cognitive Assessment (MoCA) is a popular cognitive screening tool used in stroke, but lacks sensitivity for detecting impairment in stroke-relevant domains of processing speed, non-verbal memory and executive functions. Our aim was to assess whether the test accuracy of the MoCA can be improved with additional tailored screening items targeting these three domains.

Methods: We included 196 patients admitted to an acute stroke unit at the National Hospital for Neurology and Neurosurgery, Queen Square (QS), London. Participants completed the MoCA as well as a series of additional QS-screening items designed to assess speed of processing, non-verbal memory and executive functions. Performance on the MoCA and QS screening items was compared with performance on "gold standard" neuropsychological assessment.

Results: In our sample, 22% of patients were classified as "cognitively intact" on the traditional MoCA alone (≥ 25). However, when tested on the QS-screening items, 40% of these patients failed on speed of processing, 56% failed on non-verbal memory and 26% failed on executive functions. Compared with neuropsychological assessment, the QS-screening items had good sensitivity (QS-Speed: 0.85; QS-Vis: 0.71; QS-EF: 0.73) and modest specificity (QS-Speed: 0.59; QS-Vis: 0.39; QS-EF: 0.54), regardless of stroke lateralisation.

Conclusion: Additional screening items detected impairments in speed of processing, non-verbal memory and executive functions over and above those captured using the standard MoCA. The use of these QS-screening items improves the detection of post-stroke cognitive deficits in domains not adequately covered by the standard MoCA.

1. Introduction

Stroke is one of the main causes of major disability worldwide [1]. For survivors, a stroke can be an overwhelming phenomenon entailing physical, emotional, social, and cognitive consequences. Cognitive impairment is very common but is often overshadowed by more obvious physical disabilities [2]. Impaired cognition after stroke reduces quality of life (QoL), increases dependency and depression [3], reduces functional recovery [4,5], and is associated with increased mortality [6]. Accurate early assessment of cognition following stroke has been shown to predict long-term functional outcomes [7], and is essential for informing prognosis and rehabilitation [8,9].

Due to limited time and resources, cognitive assessment in the first few weeks after stroke often takes the form of a screening tool conducted by a doctor or therapist rather than a more detailed neuropsychological assessment conducted by a trained neuropsychologist. Early identification of deficits using an optimised screening tool can flag up those patients who require further assessment which may lead to more targeted intervention and better planning for long-term goals, including complex decisions regarding ongoing rehabilitation or employment. Several reviews have recently evaluated the optimal screening tool for detecting cognitive impairment post-stroke with the best sensitivity and specificity as well as clinical utility. The Montreal Cognitive Assessment (MoCA) has been consistently identified as a promising candidate [10–12], although there is an acknowledgement that no ideal screening tool exists [11]. One main reason for this is that most cognitive screening tools, including the MoCA, were originally developed for the detection of dementia, which has a relatively

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predictable cognitive profile. In contrast, cognitive impairment after stroke can vary significantly depending on the location, size and severity of the infarct or haemorrhage. Studies that have attempted to characterize the profile of cognitive impairment after stroke have revealed mixed results. Some studies have suggested that stroke most frequently affects the domains of attention, executive functioning, spatial ability, and language [13,4], while others have suggested speed of processing is the most prevalent impairment, followed by executive functioning, naming, perceptual skills, and visual memory [14].

Given the heterogeneity of the profile of cognitive impairment after stroke, it is important that any cognitive screening tool used should assess all relevant domains to ensure that any important impairment is not missed. We conducted two recent studies to examine the accuracy of the MoCA compared with comprehensive neuropsychological assessment in a cohort of patients with recent stroke. The first study with 136 patients showed that of the 22% of patients classified by the MoCA as "cognitively intact", 78% showed impairment in at least one cognitive domain on neuropsychological assessment [15]; missed impairments were most frequent in general intelligence, processing speed, and non-verbal memory, which are not assessed by the MoCA. A high proportion of patients were also found to have executive dysfunction, a domain that is only partially assessed by the MoCA; this finding was recently replicated in another stroke cohort [16]. In a second study with a larger cohort of 228 patients, we examined whether the test accuracy of the MoCA is different for patients with left- and right-hemisphere strokes [17]. We found that patients with a right-hemisphere stroke were more likely to be classified as cognitively intact on the MoCA, despite a similar prevalence of cognitive impairment on neuropsychological assessment for the two groups. Eighty-eight percent of right-hemisphere stroke patients who had an overall MoCA-intact score were found to be impaired in at least one neuropsychological domain, with intellectual functioning, processing speed, executive functions and non-verbal memory being the most commonly affected. Furthermore, the high impairment rate on the MoCA by patients with left-hemisphere stroke most likely reflects the fact that patients with aphasia find it difficult to complete the MOCA due to the high language burden of many items, rather than "true" impairment in particular domains [18]. Taken together, these studies provide evidence that the MoCA does not optimally assess several important domains commonly affected after stroke, namely processing speed, non-verbal memory and executive functioning; the latter is an important predictor of length of stay, functional dependence, and increased burden on community therapy services [19,20]. Failure to detect or understand the cognitive changes after stroke can lead to unmet needs that can have significant negative psych-social, functional and emotional consequences [21,22].

The aim of the current study was to assess whether the test accuracy of the MoCA in an acute stroke population can be improved by using additional screening items. We supplemented the MoCA with screening items designed at Queen Square (QS) to assess processing speed, non-verbal memory and executive functioning ("QS-screening items"). The test accuracy of these additional QS-screening items was compared against gold standard comprehensive neuropsychological assessment. We also examined whether there was any bias in the test accuracy of the items by stroke lateralisation.

2. Methods

2.1. Participants

Data from 503 consecutive patients admitted to the Acute Stroke and Brain Injury Unit at the National Hospital for Neurology and Neurosurgery (NHNN), Queen Square in London between October 2014 and July 2018, and assessed by a Clinical Neuropsychologist as a part of standard routine care, was screened retrospectively for eligibility. This unit accepts patients with confirmed stroke from the London Boroughs of Camden and Islington. Inclusion criteria were a) available MoCA data, b) available Queen Square (QS) screening data, c) available neuropsychology assessment data covering at least one cognitive domain, d) confirmed ischaemic stroke or intracerebral haemorrhage. Exclusion criteria were a) traumatic brain injury, b) subarachnoid haemorrhage, or c) non-stroke diagnosis. The final sample who met the inclusion criteria comprised a total of 196 patients (Fig. 1). None of these patients were included in our previous studies investigating the MoCA (i.e. [15], [17]). Demographic and clinical information was collected at the time of assessment, which included age, sex, years of education, pathology type, and lesion side. Pathology type was categorized by ischemic stroke, haemorrhagic stroke, or a combination of both. Lesion side was classified as right, left, or bilateral. Data on stroke severity (e.g. NIHSS or OCSP) was not available.

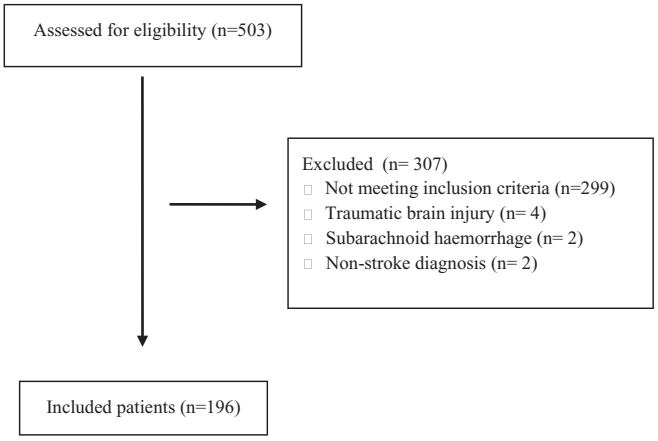

Fig. 1. Description of study population.

Our study was approved by the local clinical governance and ethics committees (joint UCL Institute of Neurology/National Hospital for Neurology and Neurosurgery) using de-identified data collected as part of routine clinical practice.

2.2. Procedure

Cognitive screening and neuropsychological assessment was conducted by fully qualified clinical neuropsychologists as part of standard routine care. All patients were administered the standard MoCA with the additional Queen Square (QS) screening items followed by a full standardized neuropsychological assessment.

2.2.1. The MoCA

The MoCA consists of 16 test items grouped into eight domains [23]. Administration and scoring was completed according to published guidelines, including adjustment for years of education (www.mocatest.org). Patients were classified as intact on the MoCA if they scored ≥ 25 out of 30. This cut-off was chosen as it has been shown to provide the optimal sensitivity and specificity for detecting cognitive impairment in a post-stroke sample [24]. For the individual domains, cognitive impairment was classified as not being able to achieve the maximum score on the specified domain.

2.2.2. The QS-screening items

The QS-screening items were grouped into three cognitive domains.

1) Information processing speed (QS-Speed) was assessed by asking patients to 1) count backwards from 30 to 1 and 2) recite the months of the year backwards from December to January as quickly as possible [25]. Cut-off scores were 25 s and 24 s respectively, with no errors allowed in the count backwards task and 1 error allowed in the months backwards task. If patients did not pass the count backwards task, they were not administered the months backwards

task. One point was given for each task. Impairment in the domain was classified as scoring < 2 points.

2) Non-verbal memory (QS-Vis) was assessed using a design memory task based on other common neuropsychological non-verbal memory tests such as the Benton Visual Retention Tests [26] and the Adult Memory and Information Processing Battery [27]. The two designs were simple abstract geometric drawings with clear definable features (see Appendix 1). The format of the design memory task was intended to align with the verbal recall task of the MoCA. Patients were asked to copy and then recall the items immediately and after a delay. One point was given for each correctly drawn design at immediate and delayed recall (maximum of 4 points). Impairment in the domain was classified as scoring < 4 points. Data was only included in the analyses if patients were able to accurately copy both designs.
3) Executive functioning (QS-EF) was assessed using two common bedside tests – the simple Motor Tapping Task and the 3-stage Luria Task [28,29]. In the Motor Tapping Task, patients were firstly asked to give the same finger tapping response, using their index finger, as the clinician in a defined sequence of 1 or 2 taps (i.e. tap once when the clinician taps once, tap twice when the clinician taps twice). Secondly, patients were asked to give the alternate (i.e. conflicting) response to that of the clinician in the same defined sequence (i.e. tap once when the clinician taps twice, and vice versa). One point was given for each correctly completed sequence (maximum of 2 points). In the 3-stage Luria Task, the patient was asked to copy and repeat independently a series of 3 hand gestures using their non-paretic hand (fist, edge, and palm). One point was given for being able to copy the gestures, one point for being able to independently repeat the sequence one to two times, and one point for being able to independently repeat the sequence more than two times (maximum of 3 points). Impairment in the domain was classified as scoring < 5 points.

2.2.3. Neuropsychological battery

The neuropsychological battery assessed six different cognitive domains including verbal and non-verbal memory, naming, perception, information processing speed, and executive functioning (see Appendix 2 for the list of tests). Due to the retrospective nature of this study, patients received a tailored collection of tests which was considered appropriate by the clinical neuropsychologist at the time, so not all patients received the exact same set of neuropsychological tests. The approximate duration of a testing session was 60–90 min and was generally completed within one testing session, after the MoCA and the QS-Screening items were administered. The neuropsychological results were scored according to published standardized normative data. For each cognitive domain, scoring below or at the fifth percentile on any subtest was categorized as impaired on that corresponding domain (for further detail, see [14]).

2.3. Statistics

Data were analysed using SPSS v.19. Between-group comparisons were made using *t*-tests and chi-squared for continuous and categorical variables respectively. Receiver operating characteristic (ROC) curve analyses were used to determine the sensitivity, specificity, negative predictive value (NPV) and positive predictive value (PPV) of the QS-screening domains and the original MoCA domains. The relative sensitivity of the MoCA with and without the addition of the QS-screening items was examined using the area under the receiver operating characteristic curves (c statistic).

3. Results

Forty-three patients (22%) were classified as intact based on their overall MoCA scores. Their demographic and clinical characteristics are shown in Table 1. Compared to patients with impaired MoCA scores, MoCA-intact patients were significantly younger and had higher estimated premorbid functioning. There were no significant differences in sex or stroke type. In the MoCA-intact group, there was almost twice the number of patients with right-hemisphere stroke compared with left-hemisphere stroke, whereas these numbers were relatively comparable in the MoCA-impaired group. Patients with right-hemisphere stroke scored significantly higher than those with left-hemisphere stroke (Right: M = 20.14, SD: 5.51, Left: M = 15.13, SD: 7.20, t (166) = −5.10, $p < .01$).

Table 1
Demographic and clinical characteristics.

Demographic and clinical characteristics	MoCA intact (n = 43)	MoCA impaired (n = 153)	Intact vs impaired
MoCA raw score (SD)	26.77 (1.33)	15.68 (5.52)	***p* < .001**
Premorbid intellectual functioning - NART	112.10 (10.45)	100.67 (15.72)	***p* = .001**
Age in years (SD)	59.16 (16.09)	67.20 (15.49)	***p* = .003**
Sex (Male/ Female)	33/10	94/59	p = .063
Time since injury (days)	7.08 (5.89)	10.71 (9.19)	p = .065
Infarct/haemorrhage	30/13	107/46	p = .983
Lesion side – right/left/ bilateral	24/13/6	69/63/21	p = .396

Bold indicates $p < 0.05$.

Of the entire sample, 77% (147 of 192 patients) failed on QS-Speed, 70% (76 of 109 patients) failed on QS-Vis and 72% (123 of 173 patients) failed on QS-EF. On neuropsychological assessment, 90% (177 of 196 patients) were impaired (scored below the 5th %ile) on at least one cognitive domain, while 76% (133 of 176 patients) were impaired in two or more domains.

A large proportion of patients who were classified as MoCA-intact failed on one or more of the QS screening items. Of the 43 MoCA-intact patients, 37% (16 patients) failed in 1 of the three QS screening domains while another 37% (16 patients) failed in at least 2 of the three QS screening domains. Patients most frequently failed in the non-verbal domain followed by the speed domain and the executive domain. Table 2 shows the percentage of patients who failed in each of the QS screening items in the MoCA-intact group.

3.1. Comparing the MoCA executive domain performance with the QS-EF screening items

From the entire sample (MoCA-intact and MoCA-impaired), 25 patients scored full marks on the Executive domain of the MoCA. Of those patients, one-third (32%) failed on the QS-EF screening items. These findings suggest that the additional QS-EF items are sensitive to executive deficits not detected by the MoCA Executive domain. Thus, the

Table 2
Percentage (%) and number (n) of patients impaired on QS-screening items in the MoCA intact group overall and for patients with left and right hemisphere strokes separately.

QS screening items	MoCA intact (n = 43)	Left (n = 13)	Right (n = 24)	Left vs Right
QS-speed	40% (17/43)	54% (7/13)	33% (8/24)	
30–1	12% (5/43)	17% (2/12)	13% (3/24)	p > .1
Months backwards	36% (15/41)	50% (6/12)	30% (7/23)	p > .1
QS-Vis	56% (19/34)	45% (5/11)	58% (11/19)	
Immediate recall	47% (16/34)	45% (5/11)	42% (8/19)	p > .1
Delayed recall	50% (17/34)	27% (3/11)	58% (11/19)	p > .1
QS-EF	26% (11/43)	23% (3/13)	35% (8/23)	
Motor tapping	7% (3/43)	0% (0/13)	10% (3/23)	p > .1
3-stage Luria	24% (8/33)	38% (3/8)	24% (5/21)	p > .1

addition of the QS-EF screening items to the MoCA resulted in 91% of the entire sample being identified as having executive deficits, compared with 86% with the MoCA alone.

Nineteen patients who were unable to be assessed on the MoCA Executive domain due to dominant hand weakness were all assessable on the QS-EF screening items; 79% of these (15 patients) failed on the QS-EF screening items.

3.2. Comparing performance on the QS screening items between patients with left and right hemisphere lesions

From the entire sample, 93% of patients with left- hemisphere stroke and 91% of patients with right-hemisphere stroke were impaired in at least one of the three QS screening domains. Of the MoCA-intact group, 69% of patients with left-hemisphere stroke and 75% of patients with right-hemisphere stroke were impaired in at least one of three QS screening domains. Table 2 shows the performance on each QS screening item by stroke laterality in the MoCA-intact group. The difference in likelihood of impairment was not statistically significant between the two groups on any of the QS screening items ($p > .1$), however the small sample size of the two groups should be taken into account.

3.3. Comparing QS-screening items and MoCA domains with neuropsychology performance

We examined the sensitivity, specificity, NPV and PPV of the QS screening items by comparing it with performance on neuropsychological assessment investigating comparable cognitive domains. Impairment on the QS screening items was defined as not achieving the maximum score. Impairment on neuropsychology assessment was defined using the criteria of scoring at or below the 5th %ile on any test in the relevant cognitive domain. The sensitivity, specificity, NPV and PPV of the three QS screening domains are reported in Table 3.

As shown, all three QS screening items have good sensitivity for detecting impairment with the QS-Speed items having the best sensitivity. The specificity of the screening items was lower particularly for QS-Vis which also had the lowest PPV. Notably though, the test accuracy for ths QS-Vis is comparable to the Verbal Memory item of the MoCA. QS-EF had the lowest NPV which reflects the high prevalence of executive dysfunction in the sample. Overall, the sensitivity, specificity, NPV and PPV for the three QS screening items appear comparable to that of the original MoCA-domain items (see Table 4).

3.4. Comparing the overall test accuracy of the MoCA with and without the QS screening items

We examined the extent to which the overall test accuracy of the MoCA can be improved with the addition of the QS screening items. We incorporated the QS screening item performance into the overall score by adding 1 point to the total score for every QS screening domain passed, making the possible maximum total score 33. Only patients who had completed neuropsychological assessment in two or more domains were included in the analysis ($n = 176$). The reference standard was impairment in two or more domains on neuropsychological assessment

Table 3
Test accuracy of QS-screening items compared with neuropsychological assessment.

	Sensitivity	Specificity	NPV	PPV
QS - screening test				
QS-speed	0.85	0.59	0.67	0.81
QS-Vis	0.71	0.39	0.67	0.44
QS-EF	0.73	0.54	0.31	0.87

Table 4
Test accuracy of MoCA domains compared with neuropsychological assessment.

	Sensitivity	Specificity	NPV	PPV
MoCA domains				
Verbal memory	0.98	0.16	0.94	0.41
Visuospatial/Executive	0.88	0.42	0.40	0.89
Naming	0.55	0.81	0.76	0.63
Abstraction	0.83	0.33	0.62	0.61
Language	0.93	0.31	0.75	0.66
Attention	0.71	0.47	0.45	0.73

Table 5
Test accuracy of the MoCA and the MoCA with the additional QS-screening items at different cut-offs for detecting cognitive impairment.

	Cut-off	Sensitivity	Specificity	NPV	PPV
MoCA (/30)	< 28	0.97	0.23	0.71	0.80
	< 27	0.95	0.35	0.71	0.82
	< 26	0.90	0.42	0.58	0.83
	< 25	0.85	0.47	0.50	0.83
	< 24	0.82	0.49	0.47	0.83
	< 23	0.77	0.56	0.44	0.84
MoCA with QS-screening items (/33)	< 28	0.93	0.40	0.65	0.83
	< 27	0.84	0.59	0.47	0.89
	< 26	0.85	0.49	0.51	0.84
	< 25	0.80	0.49	0.44	0.83
	< 24	0.77	0.53	0.43	0.84
	< 23	0.74	0.58	0.42	0.84

(133 of 176 patients; 76%). ROC curve analysis revealed that both tests were able to detect cognitive impairment; the Area Under the Curve (AUC) was highly significant, but virtually identical for both the MoCA (0.758, 95% CI. 678–0.839) and the MoCA with the addition of the QS screening domains (0.758, 95% CI. 677–0.839).

The sensitivity, specificity, NPV and PPV for the MoCA and the MoCA with the addition of the QS screening domains was calculated at different cut-offs and is shown in Table 5. Balancing sensitivity and specificity, the MoCA has an optimal cut-off at around 25/26. The MoCA with the addition of the QS screening domains has an optimal cut-off at around 26/27. As highlighted by the ROC curve analysis, the test accuracy of the two measures is comparable across the cut-off points.

4. Discussion

The primary aim of the study was to investigate the usefulness of adding QS screening items to the MoCA to detect cognitive impairment after stroke, particularly in speed of processing, non-verbal memory and executive functioning [15]. We showed that a high proportion of patients (74%) who were classified as cognitively “intact” on the MOCA failed in at least one of the three QS screening domains. Patients classed as cognitively “intact” were most frequently found to have deficits in speed of processing and non-verbal memory. The high frequency of impairment detected in these domains most likely reflects the fact that the MoCA does not assess these cognitive domains. Thus, patients who have impairment in these areas may score well on the MoCA due to intact functioning in the other domains.

A notable, though lesser, proportion of patients classified as “intact” on the MoCA, also failed on the QS-screening items assessing executive functions. Despite the MoCA having items that assess executive functions, we have previously shown that a high proportion of patients who are classed as cognitively “intact” show impairment on more stringent neuropsychological tests of executive functions [17]. Our current findings build upon this by demonstrating that these patients also fail on simple screening measures of executive functions. A third of patients who scored full marks on the Executive domain of the MoCA failed on

the QS executive items. This further supports the notion that the MoCA insufficiently assesses this important domain. One reason for this may be that the Executive subtests in the MoCA are not accurate in assessing executive abilities. For example, we have previously reported that Part-B of the Trail Making Test is not specific in detecting frontal executive dysfunction [30]; failure on the task can be a result of impairment in other cognitive domains and/or non-frontal brain regions (for a review, see [31]). Another reason may be that the MoCA items do not fully encapsulate all processes that are considered executive functions, including multiple distinctive higher-order cognitive processes such as reasoning, thinking flexibly, producing strategies, formulating and carrying out plans [32]. As such, it may be necessary to include a broader range of screening items to adequately capture all important facets of executive function. The accurate and thorough assessment of executive functions after stroke is critical, as highlighted by the NINDS-CSN VCI Harmonization Standards working group [33], as it is strongly predictive of long-term functional outcomes [19,20].

We found that our QS-screening items had good sensitivity and moderate specificity when compared with neuropsychological assessment in the same domains. The test accuracy of our items was comparable to the other items of the MoCA. Furthermore, performance on the QS screening items did not appear to be biased by stroke lateralisation, unlike items in the original MoCA which is more likely to miss deficits in patients with right hemisphere lesions [17]. This demonstrates that our test items, although brief to administer (taking only a few additional minutes), are valid measures for detecting post-stroke impairment in speed of processing, non-verbal memory and executive functions. It has been shown recently that supplementing the MoCA with more in-depth neuropsychological tests such as the Symbol Digit Modalities Test [34] can improve the accuracy of detecting post-stroke cognitive impairment, and add predictive value to measures of functional outcome [16,35]. The use of neuropsychological assessment tools are certainly preferable as they have the most robust psychometric properties and often have age-, education- and culturally-adjusted normative data to allow for the most accurate cognitive evaluation. However, administration of neuropsychological tests come with practical and resource challenges such as staff training, time constraints, the patients' physical or medical limitations that means that it is not practical to implement in every stroke patient in all stroke services so patients needing assessment may get missed. The Oxford Cognitive Screen is a domain-specific assessment tool for stroke patients that is designed to be an alternative to Neuropsychological assessment [18]. However, as the authors acknowledge, the OCS still requires more resources than the MoCA, including training, additional test materials and extra administration time [36]. Crucially, it also does not specifically include measures of processing speed or non-verbal memory and only has one item addressing executive functions. Thus, the use of the MoCA plus a few additional screening items may be a good compromise for those with limited time and resources. Early accurate detection of cognitive changes after stroke can guide appropriate referrals for more detailed assessment and/or planning of long-term goals, and reduce the likelihood of unmet needs in the community [21,22].

Despite the robust finding that the QS-screening items were able to detect deficits not detected by the MoCA, adding the performance on the QS-screening items into the scoring did not significantly improve the overall test sensitivity of the MoCA. By adding the QS-screening items to the MoCA overall score (new maximum score 33), an optimal cut-off at around 26/27 results in a test accuracy comparable to a cut-off at around 25/26 in the original MoCA. This is surprising as one would expect that increased detection of impairments not assessed by the MoCA should increase overall sensitivity. One possibility may be that impairments detected by the QS-screening items are false positives. However, this seems unlikely given the high positive predictive values we found for the QS-screening items when compared against neuropsychological assessment. Alternatively, it may be that any improvement in overall test sensitivity afforded by the QS-screening items might be obscured by the heterogeneity of post-stroke cognitive impairment. Although executive deficits and slowed processing speed are common features, focal deficits such as aphasia and visual difficulties are dependent upon the location and severity of the stroke lesion [5]. Thus, combining performance across cognitive domains to produce an overall score will always lack sensitivity compared with examining domain-specific impairment. This issue is further compounded by the fact that creating overall test cut-offs requires the need to operationalize a somewhat arbitrary criteria for “true impairment” that inevitably group impairments at the expense of domain-specificity (see [37] for a detailed discussion). Our findings are consistent with a previous study which showed that longer more detailed cognitive screening tools do not have superior overall test accuracy to shorter ones in a stroke population [38], despite the fact that more detailed tools may provide richer clinical information. Thus, targeted domain-specific assessment that covers the breadth of likely cognitive difficulties is key.

One of the main limitations of the current study is that the sample was likely biased to those more cognitively able as patients had to be able to complete the MoCA, the QS-screening items and some aspect of neuropsychological testing. As such, our findings most likely underestimate the frequency of impairment in this cohort. Unfortunately, we did not have information on the stroke severity (e.g. NIHSS or OCSP) of our population, or information regarding those who were not able to complete the necessary cognitive assessments, so we were not able to formally assess any possible bias in our sample. However, it is unlikely that patients were excluded because they were unable to complete the QS-screening items alone as the items were designed to reduce motor or language demands. Indeed, patients who were unable to be assessed on the MoCA Executive domain due to dominant hand weakness were all able to be assessed on the QS-EF screening items by using the non-dominant hand. Any language difficulties limiting patients' ability to complete the QS-speed items would also preclude them from completing the MoCA due to the high language burden [18]. The exclusion of patients with aphasia in stroke research is a long-standing limitation of the field. However, in the context of research regarding cognitive screening, one could argue that the presence of obvious aphasia already warrants more detailed and specialist assessment by a Speech and Language Therapist or Neuropsychologist, thereby negating the need for screening.

As research in the field of cognitive screening in stroke continues to develop, it is becoming increasingly important to understand how test accuracy relates to functional clinical outcomes, perhaps by adopting a test-treatment-outcome paradigm [39]. Unfortunately, a limitation of the current study was that we did not have data on the functional status and long-term outcome of our patients. A recent systematic review by Mole and Deyemere [7] did show that early cognitive impairment detected by cognitive screens and neuropsychological assessment predicted both “activity” (e.g. self care, general tasks and demands) and “participation” domains (e.g. interpersonal interactions and relationships, community, social and civic life) of the International Classification of Functioning, Disability and Health (ICF) at 6–12 months post-stroke. Notably, they showed that the relationship was more consistent when domain-specific, rather than domain-general, cognitive assessment was used. One interesting avenue to explore in future would be how performance on the QS-screening items might correlate or predict functional activities and participation, and whether domain-specific performance is more useful than the MoCA overall score.

In conclusion, we show that the use of additional QS-screening items assessing speed of processing, non-verbal memory and executive functions is feasible to capture important impairments missed by the MoCA. The addition of short screening items to the MoCA is a pragmatic solution to assessing post-stroke cognitive impairment while maintaining test brevity and utility.

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Appendix 1. The two designs used in the QS-Vis screening item

Appendix 2. List of neuropsychological tests used across domains

Verbal memory
Recognition Memory Tests (RMT), words[a]
Adult Memory and Information Processing Battery (AMIPB), story recall[b]
doors and people, People[c]

Non-verbal memory
Recognition Memory Tests (RMT), faces[a]
Adult Memory and Information Processing Battery (AMIPB), figure recall[b]
Doors and people, shapes[c]

Naming
Graded naming test[d]
Oldfield naming test[e]

Visuo-perception
Visual Object and Space Perception Battery (VOSP)[f]

Executive functions
Phonemic fluency[g]
Stroop colour word test[h]
Modified card sorting test[i]
Hayling and brixton test[j]
Weigl colour form sorting task[k]

Speed of processing
Symbol digit modalities test[l]
'0' Cancellation/ 'A' Cancellation[m]

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