Screening methods for post-stroke visual impairment: a systematic review

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ABSTRACT

Purpose: To provide a systematic overview of the various tools available to screen for post-stroke visual impairment. **Method**: A review of the literature was conducted including randomised controlled trials, controlled trials, cohort studies, observational studies, systematic reviews and retrospective medical note reviews. All languages were included and translation obtained. Participants included adults ≥18 years old diagnosed with a visual impairment as a direct cause of a stroke. We searched a broad range of scholarly online resources and hand searched articles registers of published, unpublished and ongoing trials. Search terms included a variety of MESH terms and alternatives in relation to stroke and visual conditions. Study selection was performed by two authors independently. The quality of the evidence and risk of bias was assessed using the STROBE, GRACE and PRISMA statements. **Results**: A total of 25 articles (n=2924) were included in this review. Articles appraised reported on tools screening solely for visual impairments or for general post-stroke disabilities inclusive of vision. The majority of identified tools screen for visual perception including visual neglect (VN), with few screening for visual acuity (VA), visual field (VF) loss or ocular motility (OM) defects. Six articles reported on nine screening tools which combined visual screening assessment alongside screening for general stroke disabilities. Of these, three included screening for VA; three screened for VF loss; three screened for OM defects and all screened for VN. Two tools screened for all visual impairments. A further 19 articles were found which reported on individual vision screening tests in stroke populations; two for VF loss; 11 for VN and six for other visual perceptual defects. Most tools cannot accurately account for those with aphasia or communicative deficits, which are common problems following stroke. **Conclusion**: There is currently no standardised visual

screening tool which can accurately assess all potential post stroke visual impairments. The current tools screen for only a number of potential stroke-related impairments meaning many visual defects may be missed. The sensitivity of those which screen for all impairments is significantly lowered when patients are unable to report their visual symptoms. Future research is required to develop a tool capable of assessing stroke patients which encompasses all potential visual deficits and can also be easily performed by both the patients and administered by health care professionals in order to ensure all stroke survivors with visual impairment are accurately identified and managed.

Background

Post stroke visual impairments are wide ranging affecting approximately 65% of stroke survivors and includes reduced visual acuity, ocular motility deficits, visual field loss and perceptual deficits including visual neglect (1-3). Partial or complete recovery is possible, but often these patients suffer permanent visual disability (4). Therefore, it is imperative that all elements of visual impairment are screened at the acute stage to quickly identify these patients and allow all healthcare professionals to plan rehabilitation appropriately. It is well documented that the effects of reduced visual function can have a significant negative effect on the patients' quality of life, general stroke rehabilitation and can lead to social isolation and depression (5-8).

Macintosh (2) proposed that Orthoptic visual screening in a stroke population using validated assessments can be accurately and easily undertaken. Despite this, a survey of Orthoptic practice reported 45% of stroke services did not include a formal vision assessment (9). Furthermore, when screening is undertaken, there is considerable inconsistency as to how the screening is conducted and which assessments are used (9). The purpose of this literature review is to consider the available screening methods and vision assessments used for identifying post stroke visual impairments.

METHODS

We planned an integrative review, aiming to collate evidence relating to screening tools for stroke-related visual problems. A detailed protocol was developed prior to the review. This review was carried out as part of a larger synthesis of evidence relating to visual problems after stroke. This review is conducted according to the PRISMA guidelines (10).

Inclusion Criteria for studies considered in the review

Types of studies

The following types of studies were included: systematic reviews, randomised controlled trials, controlled trials, cohort studies, observational studies, review articles and retrospective medical note reviews. Case reports were excluded due to the high risk of bias associated with these types of reports. All languages were included and translation was obtained where required.

Types of participants

We included studies of adult participants (aged 18 years or over) diagnosed with a visual impairment as a direct cause of a stroke. Studies which comprised of mixed populations were included if over 50% of the participants had a diagnosis of stroke and data were available for this subgroup. Studies were also included if the participant group consisted of health care professionals who assessed and treated visual impairment problems associated with stroke.

Search methods for identification of studies

We used systematic search strategies to search key electronic databases and contacted known experts in the field.

We searched the Cochrane Stroke Group Trials Register, the Cochrane Eyes and Vision Group Trials Register, and the following electronic bibliographic databases:

- The Cochrane Central Register of Controlled Trials (CENTRAL, The Cochrane Library, latest issue);
- MEDLINE (1950 to May 2016);
- EMBASE (1980 to May 2016);
- CINAHL (1982 to May 2016);
- AMED (1985 to May 2016);
- PsycINFO (1967 to May 2016);
- Dissertations & Theses (PQDT) database (1861 to May 2016);
- British Nursing Index (1985 to May 2016);
- PsycBITE (Psychological Database for Brain Impairment Treatment Efficacy, www.psycbite.com) (July 2004 to May 2016).

In an effort to identify further published, unpublished and ongoing trials, we:

1. Searched the following registers of ongoing trials:

i) ClinicalTrials.gov (http://clinicaltrials.gov/);

ii) Current Controlled Trials (www.controlledtrials. com);

iii) Trials Central (www.trialscentral.org);

iv) Health Service Research Projects in Progress (wwwcf.nlm.nih.gov/hsr_project/home_ proj.cfm);

v) National Eye Institute Clinical Studies Database (http://clinicalstudies.info.nih.gov/cgi /protinstitute.cgi?NEI.0.html)

2. Hand-searched the British and Irish Orthoptic Journal, Australian Orthoptic Journal, and proceedings of the European Strabismological Association (ESA), International Strabismological Association (ISA), International Orthoptic Association (IOA) (http://pcwww.liv.ac.uk/~rowef/index_files/Page646.htm) and proceedings of Association for Research in Vision and Ophthalmology (www.arvo.org);

3. Performed citation tracking using Web of Science Cited Reference Search for all included studies;

4. Searched the reference lists of included trials and review articles about vision after acquired brain injury;

5. Contacted experts in the field (including authors of included trials, and excluded studies identified as possible preliminary or pilot work).

Search terms included a variety of MESH terms and alternatives in relation to stroke and visual conditions (Table 1).

Selection of studies

The titles and abstracts identified in the primary review were independently screened by two authors (FR, LH) using the inclusion criteria discussed previously.

Where it was not possible to establish if a study met these criteria from the title or abstract, the full paper was obtained. A secondary review of the full papers was then undertaken independently by two authors (FR, LH) to determine which studies should be included. In the case of disagreement for inclusion of studies, an option was available to obtain a third author opinion (KH). In practice, this was not required as no disagreements occurred for inclusion of papers.

Data Extraction

A pre-designed data extraction form was developed. Data was extracted and documented by one researcher (LH) and verified by another (FR).

Table 1: *Search terms*

Cerebrovascular disorders/ Brain ischaemia/ Intracranial Arterial Disease Intracranial Arteriovenous Malformations/ "Intracranial Embolism and Thrombosis*/ Stroke/	Eye Movements/ Eye/ Eye Disease/ Visually Impaired Persons/ Vision Disorders/ Blindness/ Diplopia/ Vision, Binocular/ Vision, Monocular/ Visual Acuity/ Visual Fields/ Vision, Low/ Ocular Motility Disorders/ Blindness, Cortical/ Hemianopsia/ Abducens Nerve Diseases/ Abducens Nerve/ Oculomotor Nerve/ Trochlear Nerve/ Visual Perception/ Nystagmus strabismus smooth pursuits saccades depth perception stereopsis gaze disorder internuclear opthalmoplegia Parinaud's syndrome Weber's syndrome skew deviation conjugate deviation oscillopsia visual tracking agnosia hallucinations
OR	OR
AND	

Quality Assessment

One author (KH) independently assessed the quality of the studies included in this review using the following three checklists based on the type of studies identified from our search. An adapted version of the STROBE statement was used to assess the quality of cross-sectional, cohort and control studies. The STROBE statement covers 22 items from introduction, methods, results and discussion (11). The adapted version of the STROBE statement used in this review included 18 items.

The GRACE statement was used for observational studies with comparative effectiveness. This statement covers 11 items within the domains of data and methods. There is no formal scoring system used in this checklist, but it is suggested that if a paper addresses the majority of the checklist items, then it is deemed reliable (12).

Finally the PRISMA statement was used to assess quality of evidence in review articles. This covers 27 items within title, abstract, introduction, methods, results, discussion and funding (10).

All domains covered in these checklists are important factors to consider when evaluating the quality of evidence and risk of bias in the aforementioned articles. These domains were graded ‘high risk’, ‘low risk’ or ‘unclear risk’. If it is clear the domain was performed then this is described as “reported” and is recorded as having a low risk of bias. If it appears the domain was not included this is described as “not reported” and deemed a high risk of bias. Insufficient evidence is labelled as an “unclear” risk. Evidence was defined as good quality if the article reported ≥75% of the items on the relevant assessment checklist and deemed as poor quality if <50% of the items were reported.

RESULTS

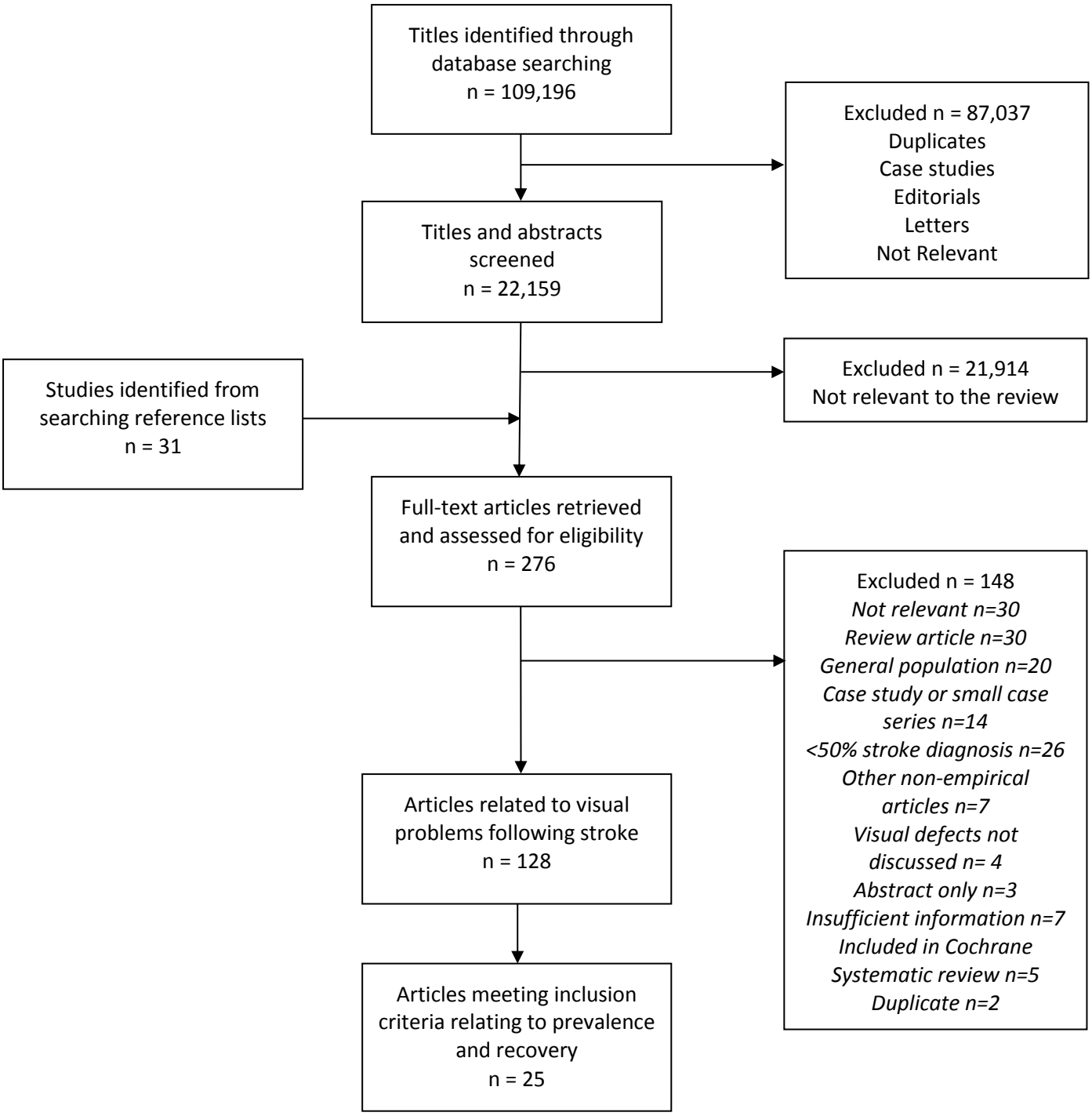
Figure 1 illustrates the results of the search. English translation was obtained for five abstracts which were then deemed unsuitable for the review. Twenty-five articles identified in the electronic and manual search met the inclusion criteria for this review. From the 25

studies appraised, two were review articles, sixteen were observational studies, and seven were observational studies with comparative effectiveness. Nine screening tools identified combined visual screening assessment alongside screening for general stroke disabilities. Of these, two screened for all visual impairment; four screened for visual acuity (VA); four screened for visual field (VF) loss; four screened for ocular motility (OM) defects and all screened for visual neglect (VN). A further 19 articles were found which reported on individual vision screening tests in stroke populations; two for VF loss; six for visual perceptual defects and 11 for VN. The results of these articles are described in Tables 2-5.

Quality of the evidence

A total of 25 articles were identified through the review and a quality of evidence assessment was undertaken for each (Tables 6-8). Two of the reported articles scored 100% in the quality of evidence assessment (13, 14). Seventeen articles reported ≥75% of the checklist items assessed and are deemed to have good quality. Three reported ≥50% of the items (15-17), and the three remaining articles failed to reach 50% (18-20).

Figure 1: *Flowchart for the pathway of included articles*



Vision Screening Tools

Two tools were identified which screened for all potential stroke-related visual impairments (21, 22): see Table 2.

Vision in Stroke (VIS) Standardised Screening Form

Rowe (22) developed a standardised visual screening form for use with stroke survivors. The initially high sensitivity was primarily due to inclusion of patient-reported visual symptoms. Sensitivity dropped to 42% in cases where the patient was unable to report symptoms such as with aphasia. Furthermore, only those patients referred with suspected visual impairment were formally examined by the Orthoptist, and thus, it is unknown how many patients were missed by the screening form.

Checklist for Vision Problems Post-Stroke

Jolly et al. (21) developed a similar screening tool for use by any healthcare professional due to the limited availability of Orthoptic input on Australian stroke units. A non-Orthoptist was considerably less sensitive using the test compared with an Orthoptist (Table 2). However, this was still significantly more sensitive when compared to the non-Orthoptists without use of the tool. This tool does not involve any clinical assessment of a patient but instead relies solely on the patient being able to answer the checklist of questions. This creates a limitation for many sub-groups of the stroke population, especially those with aphasia or cognitive problems, and likely explains why Orthoptists were unable to identify all visually impaired patients when using this tool.

Both tools were partly successful in their aims to improve detection of visual impairment in stroke survivors but clearly illustrate the need for added assessment of visual function to accurately capture the presence of visual impairment in this population.

Stroke Screening Tools

Five tools were identified that include some measures of visual function among measures of other motor and sensory functions: see Table 2.

The National Institute of Health Stroke Scale (NIHSS)

In relation to visual impairment, this tool only assesses hemianopic visual field loss, visual neglect and horizontal gaze disorders (23). This excludes screening for a wide range of ocular disorders that may occur following stroke. Therefore, it can be argued that the NIHSS cannot be used solely to screen for visual impairment in stroke patients, as it will miss impairment of central vision, other eye movement disorders and further forms of visual field loss.

The Functional Impairment Battery

Developed and described by Edwards et al. (24), this tool contains specific tests which the authors proposed had most potential to indicate impact on patients' independence. Similarly to the NIHSS, it only screens for a small number of ocular deficits; specifically visual acuity and neglect. Ocular motility and visual field assessments are excluded.

The Rivermead Perceptual Assessment Battery (RPAB)

One of the major concerns of the RPAB is that it is considered too lengthy (25). This is addressed, however, in developing the shortened battery as described below. The tool cannot be used solely for the detection of post-stroke visual impairment as it does not assess all areas of visual function. Additionally, reduced cognition and concentration can hinder the reliability of the test findings, which is a common symptom in acute stroke cohorts (25).

The Shortened Rivermead Perceptual Assessment Battery

The shortened RPAB battery takes approximately 40% less time than the full version (19). Three variations of the shortened tool were developed, although it is unclear as to which

visual assessments are included in each. Moreover, 19% of patients with perceptual problems were missed with the shortened battery compared to the full RPAB (19).

The Hemispheric Stroke Scale

All areas of visual functioning apart from visual acuity are assessed with this tool (26). However, the gaze/ eye movement assessment only seeks to identify gaze palsies or conjugately deviated gaze. Further difficulties may arise from stroke-related cognitive impairments, including aphasia, as the tool requires patients to respond to questioning of their neglect (26). Although, most aphasic patients were able to undergo the screening. The authors postulate this to be the reason why the tool is performed quicker than the RPAB (26).

Many of the tools mentioned lack full assessment of potential ocular impairments, meaning various problematic visual conditions may still go undetected. A comparison of the tools with a formal visual assessment is required to validate their accuracy of identifying stroke related visual impairments.

Visual acuity Screening Tools

Very little literature was identified regarding the testing of vision and visual acuity specifically following a stroke. Edwards et al. (24) discuss the MIS Pocket Vision Guide as an effective means of screening near visual acuity in a stroke population and their findings are shown in Table 3. Although the test detected significantly more cases of reduced vision, it should be noted that 20 of the 37 patients assessed did not have their refractive correction with them in the hospital, which potentially exaggerated the overall proportion of patients with reduced vision after stroke (24). The authors strongly advise health professionals to ask family or carers to bring glasses into the hospital.

Further tests to identify reduced visual acuity exist but have not been documented as a screening assessment in stroke populations. In the presence of aphasia, the assessment of visual problems becomes more challenging (4). However, there are assessments available for testing pre-verbal children, which could be used to overcome this problem. The Cardiff Acuity Test (CAT) is one example which estimates visual acuity by testing the principle of preferential looking (27). Although one study found the CAT to be a practical screening tool in older patients with dysphasia or cognition impairment (27), there is no reported literature considering the effectiveness of this method in a stroke population specifically.

Visual Field Screening Tools

Visual field defects are common following a stroke. However, it is often not possible to assess patients using quantitative perimetry methods at the acute stage of stroke due to co-existent general stroke disabilities (28, 29). Therefore, confrontation field assessment remains the test of choice on acute stroke wards, despite the higher risk of bias, particularly in partial defects (28, 30).

One study compared the accuracy of visual field assessment by confrontation with automated perimetry assessment on the Humphrey visual field analyser (30). This technique of confrontation field assessment is described by Goldstein & Samsa (31). Only two of ten patients with confirmed field defects using the automated perimetry assessment were identified using the confrontation technique (30). The authors speculate that an alternative method of confrontational assessment, using red or white coloured hatpins (32) is likely to provide a more effective evaluation of visual fields. The NIHSS confrontation method of finger counting is perhaps the most widely used. However due to its low sensitivity in detecting a visual field defect, it is possible that an alternative method would be more effective in the screening assessment of stroke patients (30).

A further method of confrontational field assessment has been reported by Cassidy et al. (16), which looked at the reliability of the Oculokinetic Perimetry method (OKP): see Table 3. This method has been described by Damato (33). Where the finger counting method only

detects hemianopic or quadrantic field defects, the OKP method allows for the detection of arcuate, quadrantic, hemianopic, altitudinal and nasal step defects.

The results of the study showed that, although OKP is portable and easy to use at the patients' bedsides, as well as being extremely sensitive, it requires a normal level of language, cognition and attention, which is not reflective of an acute stroke demographic (16). Very few were able to undergo the assessment, indicating that this method of confrontation field assessment is not practical in the acute stage following stroke.

Additional methods of confrontational visual field assessment exist but have not been utilised in the assessment of stroke patients (34, 35). Further research is warranted to ascertain the most effective confrontation method for bedside assessment of acute stroke survivors.

Visual Perception Screening Tools

Perceptual deficits can include visual neglect/ inattention, visual hallucinations, agnosia, alexia, depth interpretation and colour vision disturbance amongst many others (1). Careful questioning by health professionals is required to ascertain the presence of perceptual deficits in this stroke population, as patients may be unwilling to declare such problems due to fear of their mental state being questioned (1). Moreover, screening for these problems is of great importance as advice and reassurance can provide considerable relief to both the patient and families (1). This review identified six screening tools for visual perception and a further three which screen solely for visual neglect: see Table 4.

Mini Mental State Examination

The MMSE includes a domain for visual construction as well as being deemed suitable for post-stroke screening (36, 37). However, when compared to the Montreal Cognitive Assessment (MoCA), the MMSE was unable to identify as many stroke survivors with impaired cognition (38). The authors suggest one reason for this is the inability of the tool to

screen for complex impairments including visuospatial deficits following stroke. Conversely, the MMSE was found to have a significantly higher specificity score compared to the MoCA, increasing the reliability of this tool (13).

Montreal Cognitive Assessment (MoCA)

The MoCA can be performed quickly at bedside to assess post-stroke cognition following stroke. This tool includes three additional visual tasks alongside the copying task of the MMSE (39). The overall sensitivity is deemed to be high but has just 42% specificity (13). It is suggested that the MoCA and MMSE have equal sensitivity providing similar cut off scores are used for both.

Oxford Cognitive Screen (OCS)

This tool screens for post stroke cognitive impairments and includes some testing of visual perception (14). Sensitivity scores range from 27.59 to 94.12% when validated against other measures (see Table 5). It takes slightly longer to administer at bedside and the authors note infrequent reasons when subtests could not be included; problems with vision, motor impairment, comprehension, fatigue, expressive aphasia and time (14).

Occupational Therapy Perceptual Screening Test (OT-APST)

This tool has been proven reliable (40), however, a separate assessment of visual acuity, tracking, visual fields and taking a visual history is first required to provide essential information for the screening assessment (20). The tool is then modified if a visual defect is present in order to keep the assessment within the patient's field of view (40, 41). Limitations include the requirement of adequate hearing and comprehension, as well as the use of either hand for writing, which is frequently not possible in stroke populations (20).

The Leuven Perceptual Organisation Screening Test (L-POST)

This recently developed tool has yet to be trialled in stroke populations (42). It is freely available online and can be easily performed at bedside using a tablet or laptop. There is a "neglect-friendly version", however the authors emphasise that the patient must first be pre-diagnosed with visual neglect.

The Test of Visual Perceptual Skills – third edition (TVPS-3)

This tool has the benefits of enabling stroke patients to respond without the need for motor or verbal expression and can further be used in those with reading difficulties as it involves only pictures (43). However, the authors suggest enlarging the pictures and eliminating timing of the memory test to address the insufficient test-retest reliability for each subscale: see Table 5 (44).

The majority of screening tools discussed refer mostly to the assessment of visual neglect/ inattention. Cooke et al. (20) provide an evaluation of the tools available, many of which they record as being too lengthy: see Table 2. Furthermore, validation and normative data were missing from the following tools and as such they have not been included in this review: Ontario's society of OTs perceptual evaluation, the cerebrovascular accident (CVA) evaluation battery of St Mary's Hospital, Chessington OT neurological assessment battery and Baylor adult visual perceptual assessment.

Various tests have been developed to screen for unilateral visual neglect (17, 44). When combined, these tests make up the Rivermead Behavioural Inattention Test (BIT) (45). Moreover, several shorter test batteries have since been developed for testing neglect, which contain various subtests taken from the BIT and claim a more concise assessment in significantly shorter time (46, 47).

It is widely postulated that a combination of neglect tests is more effective in detecting visual neglect than any one test alone (18, 47-51). All tests have individual merits; however, a

collective battery of tests assesses a broader range of visual functions for a more accurate assessment of visual neglect.

The Sunnybrook Neglect Assessment

This battery includes four tests for neglect taken from a previously larger battery, which were deemed the most complimentary to each other (46). The SNAP is quicker to administer than the BIT and the results are reported to reflect high reliability and validity. Furthermore, the authors claim to address previously identified limitations for aphasic patients by eliminating language-based tasks. However, their pencil-and-paper tasks require handwriting and a level of cognition which may not always be possible in stroke populations.

The French Test Battery for Unilateral Neglect

Azouvi et al. (51) found that combining their three most sensitive tests gave a high sensitivity of visual neglect detection: see Table 4. This battery identified an additional 28% of patients with neglect and highlights the requirement of more than one screening test due to the multi-factorial nature of neglect. However, there is no indication of the length of time for the whole battery. This is an important factor to consider as, particularly in the acute phase following stroke, concentration and attention are frequently reduced (14). The benefit of adding further tests needs to be weighed against clinical practicalities.

Virtual Reality Diagnostic Test (VR-DiSTRO)

Fordell et al. (47) developed a computer based battery of four modified neglect tests and found that most patients felt able to focus and understand the instructions. This method is reported to be around three-times quicker to administer than the BIT. However, the computer set up indicated by the instructions would not allow assessment to be performed at the bedside and would require sufficient sitting balance. The concept of a technological form of visual screening tool is positive but would require some modification to encompass usage by

the majority of stroke survivors, such as making it more accessible in the form of portable, bedside equipment.

Sensitivity varies greatly between the various available neglect tests as seen in Table 4 (48, 49, 52). The following section describes individual paper-and-pencil tasks identified to screen for visual neglect following stroke.

The Line Bisection Test

The typical method of the Line Bisection test requires the patient to draw a line or cross where they interpret the middle of a given horizontal line to be (49). The length of the test line has differed in various studies, ranging from 50mm to 200mm, which has shown to greatly affect the accuracy of the test (49, 51). One study found the line bisection test to be one of the least reliable methods when tested with a 50mm line (49). Concurrently, a 200mm line was almost twice as effective as a 50mm line at detecting neglect (50). Lindell et al. (51) modified the line bisection test to include 12 lines, which varied between three lengths; 63mm, 123mm and 185mm. This increased the sensitivity, further indicating that larger lines should be used on the test sheet to make the assessment as sensitive as possible.

Additional studies have found the line bisection test to have a poor predictive value (52) as patients with only mild symptoms of neglect would be missed. Azouvi et al. (50) found the line bisection test to be the least sensitive measure as it was the only assessment from their battery to be significantly affected when patients used their left hand to write. However, this was only significant in the smaller 50mm line, further supporting the previous recommendation that longer lines should be used in this assessment. A separate study addresses this issue by altering the length of the line depending on which hand the patient uses (46). Although this method proved effective, they do not specify which length they used for which hand, making it difficult for health professionals to translate this method into practice.

The line bisection test has been deemed reliable in a number of studies. Luukkainen-Markkula et al. (17) found the line bisection subtest to be especially sensitive in detecting a combination of both hemispatial neglect and visual field deficits. Agrell et al. (48) reported the line bisection was the most sensitive neglect test in their comparative study. However, they postulate that performance on the line bisection test further expresses motor neglect, skewing the accuracy of the test.

The line bisection test has further been proven useful in detecting both visual neglect and extinction. Vossel et al. (53) found significantly more errors on the line bisection test in the presence of extinction. Conversely, they found no significant relationship between the cancellation inattention tests and extinction. Therefore, the line bisection test was the only inattention test reported to effectively detect both visual neglect and extinction. Unfortunately, lack of description of their computerised method of assessment does not allow for confirmation that this is a suitable bedside screening tool.

Cancellation Tests

Cancellation tasks are the most widely used pencil-and-paper assessments to investigate the presence of neglect (54) and are broadly similar in method. They require the patient to scan a page of various images, and cross out the specific target stimuli (49).

Various studies have highlighted the star cancellation tests and shape cancellation test for their accuracy in detecting visual neglect after stroke (24, 50). Both tests are similar in that they involve distractor items amongst target items (46). Comparatively, Ferber & Karnath (52) found the Bells test and the letter cancellation test to be equally effective and both significantly more sensitive than the star cancellation test. They postulate that the distractor items of the star cancellation test are easily discriminated and could yield a “pop-out” effect making it easier for the patient to detect the intended targets. Whereas, all items in the letter cancellation and Bells tests resemble each other, and so, can detect visual exploratory deficits more sensitively.

However, a more recent study identified the shape cancellation test to be the most sensitive cancellation test in screening for visual neglect (46). No direct comparison has been made between the Bells test and the letter cancellation test, thus further research is indicated in order to determine whether or not distractor items have a negative effect on cancellation tests.

A higher numbers of omissions occurred on the Bells test with older patients and less educated patients (50). The authors encourage consideration of these factors where possible using this test. Furthermore, the patient's spontaneous starting point on the page is the most sensitive measure at detecting neglect, particularly when they begin to cancel the targets in the direction of right to left (49, 50). Taking the starting point into consideration increased the sensitivity of the Bells test from 41.3%, when based on number of omissions only, to 50.5% (49).

Text Reading

Azouvi et al. (49) described the method of text reading, which considers variables such as the number of words omitted, and the difference between omissions on the left and right side. They found it had the second highest sensitivity of all the inattention tests, after the Bells test.

Caplan (15) described an alternate form of test reading, which specifically assesses left-sided neglect. The test identified an additional ten patients with neglect who had previously been missed with OT tasks. Where other assessment methods have been criticised for failing to detect mild cases of visual neglect (52), the text reading task effectively identified mild neglect in 46.5% of patients (15).

Figure copying and Drawing tasks

The methods of figure copying and drawing a clock from memory are described by Azouvi et al. (50). It has been suggested that copying an image relies more on visual input compared to drawing from memory and therefore, copying tasks are more sensitive at picking up visual

neglect (55). This is supported by Azouvi et al. (47) as the figure copying task was one of the more effective tests at detecting neglect, whilst the clock drawing test scored poorly (Table 4).

Moreover, Cooke et al. (40) noted variability in the scoring of the clock drawing test, as subtle errors made interpretation of the scoring criteria unclear. However, the authors fail to state the nature of these errors. They indicate a requirement for future research in order to re-evaluate this test and take into account the interpretation of minor errors, which could subsequently increase the reliability of this screening method.

CONCLUSION

The results of this literature review showed that there is currently no single tool which can effectively screen for all potential post-stroke visual impairments when the patient's cognitive and communicative disabilities are taken into account. As many functional deficits after stroke are not always apparent immediately, and with many patients unable to report their symptoms due to these difficulties, standardised screening protocols are needed to accurately identify individuals with visual impairments.

Furthermore, when utilised by non-eye care specialists, the efficacy of various screening methods is significantly reduced. This highlights an urgent demand for the development of a tool which can be used by any health care professional at the acute stage of stroke to identify all potential visual impairments. If identified, these patients can be referred for more thorough investigation of visual function, which will further aid planning of their general rehabilitation.

The results of this review further highlight the lack of high quality comparative studies to ascertain the validity of individual screening methods as well as overall assessment tools; an additional prerequisite for future research.

Declaration of interest

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Disclaimer

The views expressed are those of the authors and not necessarily those of the NHS, the NIHR or the department of health.

Table 2: *Screening tools for visual impairment following stroke*

Screening tool	Study	Study design	Visual impairment (s) screened	Time/ duration of tool	Accuracy of tool
Hemispheric stroke scale	Adams et al 1987 (26)	multicentre observational study	Neglect • line Bisection test with a single 20cm line Visual perception • figure-copying Gaze/ eye movement assessment Visual field assessment by confrontation and asking the patient if they are aware of all of their limbs	30 minutes	90% of aphasic patients could undergo screening *"high sensitivity as it correlates well with barthel index"*
Chessington OTneurological assessment battery (COTNAB)	Cooke et al 2005a (20)	Review	12 tests in 4 sections: • Visual perception • Constructional ability • Sensory motor ability • Ability to follow instructions	60-80 minutes	no reliability or validity documented in the literature
Lowenstein OT cognitive assessment (LOTCA)	Cooke et al 2005a (20)	Review	26 tests assessing: • orientation • visual perception • spatial perception • praxis • visuomotor organisation • thinking operations the geriatric version includes memeory testing instead of	45 minutes Geriatric version = 30-45 minutes	Not stated

			spatial perception (23 tests in total)		
Ontario's society of OT's perceptual evaluation	Cooke et al 2005a (20)	Review	28 tests assessing: • Sensation • Scanning • Apraxia • Body awareness • Spatial relations • Visual agnosia	not stated	Limited validity documentation
Rivermead Perceptual Assessment Battery (RPAB)	Cooke et al 2005a (20)	Review	16 tests assessing: • colour, • sequencing, • object completion, • figure ground discrimination, • body image, • inattention • spatial awareness	60-120m minutes (52-58 minutes Lincoln 1989)	
The functional impairment battery	Edwards et al 2006 (24)	Prospective clinical study	Near VA • MIS pocket vision guide Neglect: • star cancellation test	All participants could complete the tool in less than 1 hour None of the study measures are timed in this tool	70% sensitivity for VA assessment 52% sensitivity with star cancellation test
The Checklist for Vision Problems Post Stroke	Jolly et al 2013 (21)	retrospective study from 100 patient case histories	• Reduced visual acuity • Visual field loss • Visual neglect • Ocular motility defects	Not specified	69% sensitivity with an Orthoptist 17% sensitivity with a non-Orthoptist using the tool
Shortened RPAB	Lincoln & Edmans 1989 (19)	controlled trial	Three shortened versions: tests in each are not specified	30-35 minutes	81% sensitivity and 100% specificity 19% patients were missed compared to the full version

VIS Standardised Screening Form	Rowe 2011a (22)	large prospective multicentre observational study	• Reduced visual acuity • Visual field loss • Visual neglect • Ocular motility defects	Not specified	92% sensitivity However, without patient reported symptoms, sensitivity was 42% and specificity was 52%

Table 3: Screening methods for visual field loss following stroke

Study	**Study design**	**Population (*n*)**	**Screening tool**	**Time/ duration of assessment**	**Accuracy of tool**
Cassidy et al 2001 (16)	Prospective study (1/ 2 of the examiners was blinded)	Stroke *n*=19 (7 died by end of the 12 week follow up) Seen within one week of stroke	Oculokinetic perimetry confrontation method (OKP)	Not specified	Sensitivity 94.4% *(N.B. requires a normal level of language, cognition and attention)*
Townend et al 2007 (30)	Prospective single blinded study	*n*=61 Post stroke with homonymous visual field defect	NIHSS confrontation method	Not specified	sensitivity = 20% specificity = 98%,

Table 4: Screening methods for visual neglect following stroke

Study	**Study design**	**Population (*n*)**	**Screening tool**	**Time/ duration of tool (mins)**	**Accuracy of tool(s)**
Agrell et al 1997 (48)	Observational	Stroke *n*=57	Various: • Line bisection, • star cancellation, • Draw a clock, • copy a cross, • line crossing	not specified	Line bisection test was most sensitive (55%) Followed by star cancellation (46%), Draw a clock (42%), copy a cross (27%, And line crossing was the least sensitive (14%).
Azouvi et al 2002 (49)	Observational study (compared with previously reported control group)	Stroke patients with right hemispheric lesions *n*=206 Controls *n*=69	French test battery: • Line bisection, • Bells test, • Text reading, • figure copying, • clock drawing, • overlapping figures, • Writing	No time limit given. Only Bells test was timed. Average time to complete all tasks not specified	Line bisection: 19% sensitivity with 5cm line. 37.7% sensitivity with 20cm line Text reading: 46.8% Figure copying: 42.7% Clock drawing: 27.8% Bells test: 50.5% overlapping figures:30.7% writing: 34.35 whole battery together = 85.9% sensitivity
Azouvi et al. 2006 (50)	Prospective Observational study (compared with control group)	Stroke *n*=295 Right *n* =206 Left *n*=89 Healthy individuals (*n*=456-576 depending on the task)	French test battery: • Line bisection, • Bells test, • Text reading, • figure copying, • clock drawing • overlapping figures • writing	Not specified	Sensitivity results unclear in articles. 20cm line nearly twice as effective as 5cm line Shape cancellation =41% sensitivity combination of shape cancellation, complex line bisection and star cancellation = 88% sensitivity Adding two part picture,

					articles reading and object finding = 100% sensitivity
Caplan 1987 (15)	prospective observational study	*n*=66 Stroke *n* =64 non-stroke *n*=2	modified text reading	3 mins Time to complete task was deemed of little use as this depended on the degree of neglect and not a reflection on the test	identified mild neglect in 46.5% of patients, and severe neglect in 25.6%
Cermak & Lin 1994 (18)	Review	Right cerebral vascular accident *n*= not specified: method of review not included	• Copying or drawing tests, • Line bisection, • Cancellation tests, • Reading tests, • The BIT	Cancellation tasks can be completed in less than 2 mins	Line bisection = 76% sensitivity *Black et al 1990* (55)
Ferber & Karnath 2001 (52)	prospective observational study	Right sided stroke *n*=35	• Line bisection • Line crossing • Bells test • Letter cancellation • Star cancellation • clock drawing • copying task • baking tray task	not specified	Line bisection failed to detect 40% of neglect cases. The exact sensitivity unclear as mean values were not calculated Line crossing: 29.6% omissions detected bells test: 61% omissions detected Letter cancellation: 62% omissions detected Star cancellation: 40% omissions detected
Fordell et al 2011 (47)	prospective observational study	Stroke *n*=31	<u>V-DiSTRO</u> • Line bisection, • star cancellation, • visual extinction, • baking tray test	Mean assessment time for entire tool was 15 mins Reported 50 mins for	• Overall, 100% sensitivity and 82% specificity. • Star cancellation: 54% sensitivity and 96%

				BIT, therefore VR-DiSTRO was 3x quicker than BIT	specificity. • Line bisection: 33% sensitivity and 100% specificity. • baking tray task: 100% sensitivity and 86% specificity • Extinction: 100% sensitivity and 95% specificity
Leibovitch et al. 2012 (46)	Prospective observational	Stroke *n*=224 (right sided *n*=125, left sided *n*=99)	<u>SNAP</u> • Spontaneous drawing of clock and daisy • Line cancellation • Line bisection (15cm and 20cm) • Copying of clock and daisy • Shape cancellation	*"speed of administration is a key strength to the SNAP"* Average length of time to complete the tool not specified	Overall sensitivity of the SNAP = 68% and specificity = 76% Shape cancellation = most sensitive test (70%) Drawing/ copying = most specific (99%)
Lindell et al. 2007 (51)	Prospective observational	Stroke *n*=30	<u>Various</u>: • Line crossing • Letter cancellation • Star cancellation • Line bisection (3xlines) • Complex line bisection (12x lines) • Figure and shape copying • Sentence copying • Representational drawing • Object finding • Picture scanning • Two part picture • Slide • Article reading • Personal neglect		Sensitivity: • Line crossing = 26% • Letter cancellation = 32% • Star cancellation = 41% • Line bisection = 38% • Complex line bisection = 48% • Figure and shape copying = 29% • Sentence copying = 18% • Representational drawing = 6% • Object finding = 21% • Picture scanning = 21%

					• Two part picture = 32% • Slide = 13% • Article reading = 36% • Personal neglect = 29% All had 100% specificity apart from shape cancellation, star cancellation, two-part picture which had 89%, 90% and 90% respectively The three most sensitive tests (Random Shape cancellation, Complex Line bisection, Star cancellation) together had 88% sensitivity
Luukkainen-Markkula et al 2011 (17)	Prospective Observational	Right hemispheric stroke patients with hemi spatial neglect *n*=17	• Line cancellation • Letter cancellation • Star cancellation • figure and shape copying • line bisection • drawing	Not specified	Only the line bisection test correlated significantly with the Catherine Bergego scale
Vossel et al 2011 (53)	Control study	Right hemispheric stroke *n*=56	• Line bisection • line cancellation • star cancellation • figure copying • text reading • clock drawing A “novel computerised task” was used to test for extinction and neglect	180 ”trials” in total but length of each trial is not specified	Positive correlation found between line bisection test only and extinction

Table 5: Screening tools for visual perception following stroke

Study	**Study design**	**Population (*n*)**	**Screening tool**	**Time/ duration of tool (mins)**	**Accuracy of tool**
Chiu et al 2016 (43)	Prospective repeated measures design	Stroke *n*=50	<u>TVPS-3</u> 7 subscales (2 practice items and 16 test items): • Visual discrimination • Visual memory • Spatial relations • Form constancy • Sequential memory • Visual figure-ground • Visual closure	40	Overall intraclass correlation coefficient = 0.92 Visual discrimination = 0.64 Visual memory = 0.53 Spatial relations = 0.82 Form constancy = 0.55 Sequential memory = 0.66 Visual figure-ground = 0.67 Visual closure = 0.77
Cullen et al 2007 (36)	Review	-	Various <u>MMSE</u> 30 items *This was the only tool identified which was deemed suitable for post-stroke screening and contained a visual perception domain*	10-15	0.82 internal consistency *McDowell et al1997 (56)* 0.85 test-retest *Correa et al 2001 (57)*
Cooke et al 2005a (20)	Review	-	<u>OT-APST</u> 25 items: • Agnosias (5 items) • Visuospatial relations including neglect (5 items) • Body scheme (4items) • Constructional skills (3 items) • Apraxia (6 items) • Alcalculia (1 item) • Functional skills (5 items)	20-25	-
Cooke et al 2005b (40)	Prospective observational	Stroke *n*=25	OT- APST (as above)	30	Interrater reliability = 0.66-1.0

	study	*n*=15 for interrater and intrarater reliability study *n*=10 for test-retest study			Intrarater reliability = 0.64-1.0 Test-retest reliability = 0.76-0.95
Cooke et al 2006 (41)	Series of observation studies, compared with control group	Stroke admissions over one year *n*=208 (healthy controls *n*=356)	OT-APST (as above)	30	Intraclass correlation coefficient range = 0.6-1.0
Demeyere et al 2015 (14)	Control trial	Stroke *n*=208 Neurologically healthy controls *n*=140	<u>OCS</u>: Picture naming Semantics Orientation free Orientation MCQ Visual field Sentence reading Number writing Calculation Broken hearts Space asymmetry Object asymmetry Imitation Verbal recall Verbal recognition Episodic Recognition Executive task	15-20	Sensitivity and specificity values when validated against other tools: Picture naming: 59.32% sensitivity and 72.92% specificity Semantics: 27.59% 98.31% Orientation free: 68.00% 87.38% Orientation MCQ: 52.00% 92.23% Sentence reading 62.97% sensitivity and 81.94% specificity Number writing 52.63% sensitivity and 70.10% specificity Calculation 45.45% sensitivity and 91.14% specificity Broken hearts 94.12% sensitivity and 69.01% specificity

					Space asymmetry 65.63% sensitivity and 75.00% specificity Object asymmetry 46.88% sensitivity and 91.07% specificity Imitation 72.20% sensitivity and 90.70% specificity Verbal recall: no cut offs Verbal recognition: no cut offs Episodic Recognition 75.00% sensitivity and 73.53% specificity Executive task 66.67% 74.19% Visual field: was not compared to other measure for validation. Test-retest reliability = 83.3% sensitivity and 93.48% specificity
Dong et al 2010 (38)	Prospective observational study	Stroke *n*=100	MMSE (as above) MoCA: 7 subtests • Visuospatial/ executive functions • Naming • Memory • Attention • Language-sentence repetition • Language-verbal fluency	Not specified	MMSE identified 43 patients with impaired cognition MoCA identified 59 patients with impaired cognition
Godefory et al 2011 (13)	Prospective observational study	Stroke *n*=95	MMSE (as above) MoCA (as above)	Not specified	MMSE: 66% sensitivity and 97% specificity MoCA: 94% sensitivity and 42% specificity

Table 6: Quality appraisal of articles using the GRACE checklist

	Data						Methods				
	D1	D2	D3	D4	D5	D6	M1	M2	M3	M4	M5
Azouvi et al 2002 (49)	+	+	+	+	?	+	n/a	-	+	?	+
Azouvi et al 2006 (50)	+	+	+	+	+	+	n/a	-	+	-	+
Cooke et al 2006 (41)	+	+	+	+	+	+	n/a	+	+	-	+
Leibovitch et al 2012 (46)	+	+	+	+	-	+	n/a	+	+	?	+
Lincoln & Adams 1989 (19)	+	+	?	-	?	?	+	-	?	n/a	n/a
Lindell et al 2007 (51)	+	+	+	+	+	+	n/a	?	+	-	+
Vossel et al 2010 (53)	+	+	+	-	+	+	+	+	+	n/a	n/a

[-] = Not reported [?] = Unclear [+] = Reported

Table 7: Quality appraisal of articles using the PRISMA checklist

	Title	Abstract	Introduction		Methods											Results								Discussion		Funding
			Rational	Questions	Existing review protocol	Study Characteristics	Sources	Search strategy	Study selection	Data extraction	Variables	Risk of Bias	Summary measures	Data handling	Risk of Bias (cumulative)	Additional analyses	No. of studies	Characteristics data extraction	Risk of Bias (individual)	Benefits or Harms	Meta-analyses	Risk of Bias (across studies)	Additional analyses	Summary	Limitations	Generalisability	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Cermak et al 1994 (18)	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	n/a	-	n/a	+	-	-	-
Cooke et al 2005a (20)	-	+	+	+	-	+	-	-	-	-	-	-	-	-	-	-	+	+	-	+	n/a	-	n/a	+	+	+	+

- = Not reported
? = Unclear
+ = Reported

Figure 4: Quality appraisal of articles using the STROBE checklist

	Methods									Results					Discussion		
	Study design	Participants	Variables	Data source	Bias	Study size	Quantitative variables	Statistical methods	Participants	Descriptive data	Outcome data	Main results	Other analyses	Key results	Limitations	Interpretation	Generalisability
	4	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Adams et al 1987 (19)	+	+	+	-	+	+	+	+	-	+	-	n/a	+	+	+	+	+
Agrell et al 1997 (48)	+	?	+	-	+	+	+	+	+	+	+	-	n/a	+	+	+	+
Caplan et al 1987 (15)	+	+	-	+	-	-	?	-	+	+	+	-	n/a	+	-	+	+
Cassidy et al 2001 (16)	+	+	+	-	+	+	-	-	?	+	+	-	n/a	+	+	+	+
Chiu et al 2016 (43)	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+
Cooke et al 2005b (40)	+	+	+	+	+	+	+	+	+	+	+	+	n/a	+	+	+	+
Demeyere et al 2015 (14)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Dong et al 2010 (38)	?	+	-	+	+	+	+	+	+	+	+	-	+	+	-	+	+
Edwards et al 2006 (24)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Ferber et al 2001 (52)	+	+	+	+	+	-	-	+	-	+	+	+	n/a	+	+	+	+
Fordell et al 2011 (47)	+	+	+	+	+	+	+	+	+	+	+	+	n/a	+	+	+	+
Godefroy et al 2011(13)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Jolly et al 2013 (21)	+	n/a	+	+	+	+	+	+	+	-	+	+	n/a	+	+	+	+
Luukainen-Markkula et al 2011 (17)	+	+	+	-	-	+	+	+	?	+	+	-	+	+	-	+	+
Rowe et al 2011a (8)	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+
Townend et al 2007 (30)	+	+	+	+	+	+	+	+	?	+	+	+	n/a	+	+	+	+

[-] = Not reported [?] = Unclear [+] = Reported

References

1. Rowe F, Brand D, Jackson C.A, Price A, Walker L, Harrison S, et al. Visual impairment following stroke: do stroke patients require vision assessment? Age & Ageing. 2009;38(2):188-93.

2. Macintosh C. Stroke re-visited: visual problems following stroke and their effect on rehabilitation. British journal of ophthalmology. 2003;60:10-4.

3. Hepworth LR, Rowe F.J, Walker M.F, Rockliffe J, Noonan C, Howard C, Currie J. Post-stroke visual imapirment: a systematic literature review of types and recovery of visual conditions. Ophthalmology research: an international journal. 2016;5(1):1-43.

4. Sand K.M, Midelfart A, Thomassen L, Melms A, Wilhelm H, Hoff JM. Visual impairment in stroke patients-a review. Acta Neurologica Scandinavica. 2013 Supplementum; (196):52-6.

5. Jonsson A.C, Lindgren I, Hallstrom, B, Norrving, B, Lindgren, A. Determinants of quality of life in stroke survivors and their informal caregivers. Stroke. 2005;36:803-8.

6. Jones S.A, Shinton R.A. Improving outcome in stroke patients with visual problems. Age & Ageing. 2006;35(6):560-5.

7. Papageorgiou E, Hardiess G, Schaeffel F, Wiethoelter H, Karnath HO, Mallot H, et al. Assessment of vision-related quality of life in patients with homonymous visual field defects. Graefes Arch Clin Exp Ophthalmol. 2007;245(12):1749-58.

8. Rowe F.J. The importance of accurate visual assessment after stroke. Expert Review of Ophthalmology. 2011;6(2):133-6.

9. Rowe F.J, Walker M, Rockliffe J, Pollock A, Noonan C, Howard C, Hepworth L, Glendinning R, Currie J. Care provision and unmet needs for post stroke visual impairment. 2013.

10. Moher D, Liberati A, Tetzlaff J, Altman D.G. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Journal of Clinical Epidemiology. 2009;62:1006-12.

11. Elm EV, Altman, D. G., Egger, M., Pocok, S. J., Gotzsche, P. C. & Vandenbroucke, J. P. Strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. Preventative Medicine. 2007;45:247-51.

12. Dreyer NA, Velentgas, P, Westrich, K, Dubois, R. The GRACE Checklist for rating the quality of observational studies of comparative effectiveness: a tale of hope and caution. Journal of Managed Care and Speciality Pharmacy. 2014;20:301-8.

13. Godefroy O, Fickl A, Roussel M, Auribault C, Bugnicourt J.M, Lamy C. Is the Montreal Cognitive Assessment Superior to the Mini-Mental State Examination to Detect Poststroke Cognitive Impairment?: A Study With Neuropsychological Evaluation. Stroke. 2011;42(6):1712-6.

14. Demeyere N, Riddoch M.J, Slavkova E.D, Bickerton W-L, Humphreys G.W. The Oxford Cognitive Screen (OCS): Validation of a stroke-specific short cognitive screening tool. Psychological Assessment. 2015;27(3):883-94.

15. Caplan B. Assessment of Unilateral Neglect: A New Reading Test. Journal of Clinical and Experimental Neuropsychology. 1987;9(4):359-60.

16. Cassidy T.P, Bruce D.W, Gray C.S. Visual field loss after stroke: Confrontation and perimetry in the assessment of recovery. Journal of Stroke and Cerebrovascular Diseases. 2001;10(3):113-7.

17. Luukkainen-Markkula R, Tarkka I, Pitkanen K, Sivenius J, Hamalainen H. Comparison of the Behavioural Inattention Test and the Catherine Bergego Scale in assessment of hemispatial neglect. Neuropsychological Rehabilitation. 2011;21(1):103-16.

18. Cermak S.A, Lin K.C. Assessment of unilateral neglect in individuals with right cerebral vascular accident. Topics in Geriatric Rehabilitation. 1994;10(2):42-55.

19. Lincoln N.B, Adams, J.A. A shortened version of the rivermead perceptual assessment battery? Clinical Rehabilitation. 1989;3:199-204.

20. Cooke D.M, McKenna K, Fleming J. Development of a standardized occupational therapy screening tool for visual perception in adults. Scandinavian Journal of Occupational Therapy. 2005;12(2):59-71.

21. Jolly N, MacFarlane A, Heard R. Towards gaining the best information about vision to assist the recovery of a patient with stroke. Strabismus. 2013;21(2):145-9.

22. Rowe FJ. Accuracy of referrals for visual assessment in a stroke population. Eye. 2011;25(2):161-7.

23. Lyden P, Lu M, Jackson C, Marler J, Kothari R, Brott T, et al. Underlying Structure of the National Institutes of Health Stroke Scale: Results of a Factor Analysis. Stroke. 1999;30(11):2347-54.

24. Edwards D.F, Hahn M.G, Baum C.M, Perlmutter M.S, Sheedy C, Dromerick A.W. Screening patients with stroke for rehabilitation needs: Validation of the post-stroke rehabilitation guidelines. Neurorehabilitation and Neural Repair. 2006;20(1):42-8.

25. Jesshope H.J, Clark M.S, Smith D.S. The Rivermead Perceptual Assessment Battery: its application to stroke patients and relationship with function. Clinical Rehabilitation. 1991;5(2):115-22.

26. Adams R.J, Meador K.J, Sethi K.D, Grotta J.C, Thomson D.S. Graded neurologic scale for use in acute hemispheric stroke treatment protocols. Stroke. 1987;18:665-9.

27. Johansen S.A, Shinton R.A. Screening for visual impairment in older people: validation of the Cardiff Acuity Test. Archives of Gerontolgy and Geriatrics. 2003;36:289-93.

28. Rowe F.J, Seuke H, Gawley S.D. Comparison of Damato campimetry and Humphrey automated perimetry results in a clinical population British journal of ophthalmology. 2010;94(6):757-62.

29. Gilhotra J.S, Mitchell P, Healey P.R, Cumming R.G, Currie J. Homonymous visual field defects and stroke in an older population. Stroke. 2002;33(10):2417-20.

30. Townend B.S, Sturm J.W, Petsoglou C, O'Leary B, Whyte S, Crimmins D. Perimetric homonymous visual field loss post-stroke. Journal of Clinical Neuroscience. 2007;14(8):754-756.

31. Goldstein L.B, Samsa G.P. Reliability of the National Institutes of Health Stroke Scale: Extension to Non-Neurologists in the Context of a Clinical Trial. Stroke. 1997;28(2):307-10.

32. Elliot D.B, North, I, Flanagan J. Confrontation visual field tests. Opthal Physiol Opt. 1997;17(2):17-24.

33. Damato B.E. Oculokinetic perimetry: a simple visual field test for use in the community. British journal of ophthalmology. 1985;69:927-31.

34. Kodsi S.R, Younge B.R. The four-meter confrontation visual field test. Journal of Clinical Neuro-ophthalmology. 1993;34(4):359-68.

35. Johnson L, N., Baloh, F.G. The accuracy of confrontation visual field test in comarison with automated perimetry. Journal of the national medical association. 1991;83(10):895-8.

36. Cullen B, O'Neill B, Evans J.J, Coen R.F, Lawlor B.A. A review of screening tests for cognitive impairment. Journal of Neurology, Neurosurgery, and Psychiatry. 2007;78(8):790-799.

37. Ridha B, Rossor M. The mini mental state examination. Practical Neurology. 2005;5:298-303.

38. Dong Y, Sharma V.K, Chan B.P-L, Venketasubramanian N, Teoh H.L, Seet R.C.S. The Montreal Cognitive Assessment (MoCA) is superior to the Mini-Mental State Examination (MMSE) for the detection of vascular cognitive impairment after acute stroke. Journal of the Neurological Sciences. 2010;299(1–2):15-8.39.

39. Wittich W, Phillips N, Nasreddine Z.S, Chertkow H. Sensitivity and Specificity of the Montreal Cognitive Assessment Modified for Individuals Who Are Visually Impaired. Journal of Visual Impairment & Blindness. 2010;104(6):360-8.

40. Cooke D.M, McKenna K, Fleming J, Darnell R. The reliability of the Occupational Therapy Adult Perceptual Screening Test (OT-APST). British Journal of Occupational Therapy. 2005;68(11):509-17.

41. Cooke D.M, McKenna K, Fleming J, Darnell R. Construct and ecological validity of the Occupational Therapy Adult Perceptual Screening Test (OT-APST). Scandinavian Journal of Occupational Therapy. 2006;13(1):49-61.

42. Torfs K, Vancleef K, Lafosse C, Wagemans J, De-Wit L. The Leuven Perceptual Organization Screening Test (L-POST), an online test to assess mid-level visual perception. Behavior Research Methods. 2013;46(2):472-87.

43. Chiu E-C, Wu W-C, Chou C-X, Yu M-Y, Hung J-W. Test-Retest Reliability and Minimal Detectable Change of the Test of Visual Perceptual Skills-Third Edition in Patients With Stroke. Archives of Physical Medicine and Rehabilitation. 2016; in press. 1-7.

44. Hartman-Maeir A, Katz N. Validity of the Behavioral Inattention Test (BIT): relationships with functional tasks. American Journal of Occupational Therapy. 1995;49(6):507-16.

45. Halligan P.W, Cockburn J, Wilson B.A. The behavioural assessment of visual neglect. Neuropsychological Rehabilitation. 1991;1(1):5-32.

46. Leibovitch F.S, Vasquez B.P, Ebert P.L, Beresford K.L, Black S.E. A short bedside battery for visuoconstructive hemispatial neglect: Sunnybrook Neglect Assessment Procedure (SNAP). Journal of Clinical & Experimental Neuropsychology: Official Journal of the International Neuropsychological Society. 2012;34(4):359-68.

47. Fordell H, Bodin K, Bucht G, Malm J. A virtual reality test battery for assessment and screening of spatial neglect. Acta Neurologica Scandinavica. 2011;123(3):167-74.

48. Agrell B.M, Dehlin O.I, Dahlgren C.J. Neglect in elderly stroke patients: A comparison of five tests. Psychiatry and Clinical Neurosciences. 1997;51(5):295-300.

49. Azouvi P, Samuel C, Louis-Dreyfus A, Bernati T, Bartolomeo P, Beis J-M, Chokron S, Leclercq M, Marchal F, Martin Y, de Montety G, Olivier S, Perennou D, Pradat-Diehl P, Prairial C, Rode G, Siéroff E, Wiart L, Rousseaux M. Sensitivity of clinical and behavioural tests of spatial neglect after right hemisphere stroke. J Neurol Neurosurg Psychiatry. 2002;73:160-6.

50. Azouvi P, Bartolomeo P, Beis J.M, Perennou D, Pradat-Diehl P, Rousseaux M. A battery of tests for the quantitative assessment of unilateral neglect. Restorative Neurology & Neuroscience. 2006;24(4-6):273-85.

51. Lindell A.B, Jalas M.J, Tenovuo O, Brunila T, Voeten M.J.M, Hämäläinen H. Clinical assessment of hemispatial neglect: Evaluation of different measures and dimensions. Clinical Neuropsychologist. 2007;21(3):479-97.

52. Ferber S, Karnath H.O. How to assess spatial neglect--line bisection or cancellation tasks? Journal of Clinical & Experimental Neuropsychology: Official Journal of the International Neuropsychological Society. 2001;23(5):599-607.

53. Vossel S, Eschenbeck P, Weiss P.H, Weidner R, Saliger J, Karbe H. Visual extinction in relation to visuospatial neglect after right-hemispheric stroke: quantitative assessment and statistical lesion-symptom mapping. Journal of Neurology, Neurosurgery & Psychiatry. 2011;82(8):862-8.

54. Bowen A, McKenna K, Tallis R.C. Reasons for the variability in the reported rate of occurance of unilateral neglect after stroke. Stroke. 1999;30:1196-202.

55. Halligan P.W, Robertson I.H. The assessment of unilateral neglect Lawrence Erlbaum associates; 1992.

56. Black S.E. Vu B, Martin D, Szalai J.P. Evaluation of a bedside battery for hemispatial neglect in acute stroke. Journal of Clinical and Experimental Neuropsychology. 1990;12(1):109.

57. McDowell I, Kristjansson B, Hill G.B, Hébert R. Community screening for dementia: The Mini Mental State Exam (MMSE) and modified Mini-Mental State Exam (3MS) compared. Journal of Clinical Epidemiology. 1997;50(4):377-83.

58. Correa J, Perrault A, Wolfson C. Reliable Individual Change Scores on the 3MS in Older Persons With Dementia: Results From the Canadian Study of Health and Aging. International Psychogeriatrics. 2001;13(1): 71-8.