Post-stroke Visual Impairment: A Systematic Literature Review of Types and Recovery of Visual Conditions

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Authors’ contributions

This work was carried out in collaboration between all authors. Author LRH ran searches, identified relevant studies, acted as first review author, extracted data, entered data, provided content expertise and co-wrote the final drafts. Author FJR led this review, provided methodological expertise, acted as a second review author, carried out analyses, and co-wrote the final drafts. Authors MFW, JR, CN, CH and JC provided additional content expertise, read and commented on final drafts and acted as additional reviewers where there was uncertainty or disagreement. All authors read and approved the final manuscript.

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ABSTRACT

Aim: The aim of this literature review was to determine the reported incidence and prevalence of visual impairment due to stroke for all visual conditions including central vision loss, visual field loss, eye movement problems and visual perception problems. A further aim was to document the reported rate and extent of recovery of visual conditions post stroke.

Methods: A systematic review of the literature was conducted including all languages and translations obtained. The review covered adult participants (aged 18 years or over) diagnosed with a visual impairment as a direct cause of a stroke. Studies which included mixed populations were included if over 50% of the participants had a diagnosis of stroke. We searched scholarly online resources and hand searched journals and registers of published, unpublished and ongoing trials. Search terms included a variety of MESH terms and alternatives in relation to stroke and visual conditions. The quality of the evidence was assessed using key reporting guidelines, e.g. STROBE, CONSORT.

Results: Sixty-one studies (n=25,672) were included in the review. Overall prevalence of visual impairment early after stroke was estimated at 65%, ranging from 19% to 92%. Visual field loss reports ranged from 5.5% to 57%, ocular motility problems from 22% to 54%, visual inattention from 14% to 82% and reduced central vision reported in up to 70%. Recovery of visual field loss varied between 0% and 72%, with ocular motility between 7% and 92% and visual inattention between 29% and 78%.

Conclusion: The current literature provides a range of estimates for prevalence of visual impairment after stroke. Visual impairment post stroke is a common problem and has significant relevance to the assessment and care these patients receive. Prospective figures regarding incidence remain unknown.

Keywords: Incidence; prevalence; visual impairment; stroke; recovery; review.

1. INTRODUCTION

Types of visual impairment following stroke can be complex including ocular as well as cortical damage [1-6]. Visual impairment can have a wide ranging impact on activities of daily living, independence and quality of life. Links with depression have also been found [7-11]. Many studies provide information on prevalence of various visual conditions from their sample based on cross section and case note observation studies [12-17]. Accurate estimates of prevalence or incidence of visual impairment for stroke survivors remains unknown. Determination of prevalence of visual impairment in a stroke unit is important in order to enable appropriate planning of efficacious referrals to an eye specialist for assessment, treatment and targeted advice [6,18,19].

The aim of this systematic literature review was to provide a comprehensive synthesis and exploration of reported evidence relating to visual problems after stroke with specific attention to incidence and prevalence.

1.1 Visual Impairment Definitions

Visual impairment is a deficit of visual function and includes abnormalities of peripheral vision, central vision, eye movements and a variety of perception problems [1,3,4,20].

Visual field loss is loss of a section of the field of vision and can either be central or peripheral. Following stroke visual field loss is frequently homonymous, with a loss in the same half of the visual field of both eyes. The types of visual field loss can include, hemianopia, quadrantanopia, constriction and scotomas [20,21]. It is also possible to have a loss of the central area of vision.

There are a wide range of ocular motility problems which can occur as a result of stroke including strabismus, cranial nerve palsies, gaze palsies, vergence abnormalities and nystagmus [22]. Strabismus is the misalignment of the eyes, which can be longstanding from childhood or occur as a result of an insult to the extra-ocular muscles or the cranial nerves supplying them. Eye movement palsies or pareses following stroke can include cranial nerve palsy, horizontal gaze palsy and/or vertical gaze palsy. Nystagmus is a continuous oscillatory movement of the eyes and is frequently associated in which both eyes move symmetrically. It may occur in every position of gaze or only be present in certain gaze positions. A further consideration is
that patients commonly have multiple defects concurrently [23].

There are a number of different perceptual problems which can occur after stroke. The most recognised is visual inattention/neglect, in which the individual does not respond or attend to visual stimuli on the affected side. Other perceptual problems are also reported such as agnosia, visual hallucinations and image movement problems [24].

2. METHODS

We conducted an integrative review, aiming to bring together all evidence relating to incidence, prevalence and recovery from stroke-related visual problems. The review observed and is reported according to the PRISMA guidelines (Appendix 1). This review was not registered with PROSPERO [25].

2.1 Inclusion Criteria for Considering Studies for This Review

2.1.1 Types of studies

The following types of studies were included: randomised controlled trials, controlled trials, prospective and retrospective cohort studies and observational studies. Case reports and case-controlled studies were excluded, as they specifically look at selected cases and are therefore unable to report incidence or prevalence. All languages were included and translations obtained when necessary.

2.1.2 Types of participants

We included studies of adult participants (aged 18 years or over) diagnosed with a visual impairment as a direct result of a stroke. Studies which included mixed populations were included if over 50% of the participants had a diagnosis of stroke and data were available for this subgroup.

2.1.3 Types of outcome and data

We defined incidence as the number of new cases of any visual condition occurring during a certain period in a stroke survivor population. We defined prevalence as the number of cases of any visual condition present in a stroke survivor population at a certain time. We defined a measure of recovery as being present if prevalence figures were available at more than one time point post stroke. The visual impairments included are defined below.

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2.3 Search Methods for Identification of Studies

We used systematic strategies to search key electronic databases and contacted known individuals conducting research in stroke and visual impairment. We searched Cochrane registers and electronic bibliographic databases (Appendix 2). In an effort to identify further published, unpublished and ongoing trials, we searched registers of ongoing trials, hand-searched journals and conference transactions,
performed citation tracking using Web of Science Cited Reference Search for all included studies, searched the reference lists of included trials and review articles about vision after acquired brain injury and contacted experts in the field (including authors of included trials, and excluded studies identified as possible preliminary or pilot work). Search terms included a comprehensive range of MeSH terms and alternatives in relation to stroke and visual conditions (Appendix 2).

2.4 Selection of Studies

The titles and abstracts identified from the search were independently screened by two authors (FR, LH) using the pre-stated inclusion criteria. The full papers of any studies considered potentially relevant were then considered and the selection criteria applied independently by two reviewers (FR, LH). In the case of disagreement for inclusion of studies, an option was available to obtain a third author opinion (CN).

2.5 Data Extraction

A pre-designed data extraction form was used which gathered information on sample size, study design, assessments undertaken, visual conditions reported, timing of assessment and population type. Data was extracted and documented by one researcher (LH) and verified by another (FR).

2.6 Data Analysis

Due to the heterogeneous nature of the studies, a narrative analysis was undertaken. The exception to this was a calculation to estimate the prevalence of overall visual impairment following stroke. Strict criteria of only studies using consecutive recruitment from a stroke population and reporting an overall prevalence for visual impairment were used for the mean prevalence calculation.

2.7 Quality Assessment

To assess the quality of the studies included in this review, two checklists were considered relevant to the study designs in our inclusion criteria: the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) checklist [26,27]. The checklist was adapted as the original was designed to assess the quality of reporting rather than the potential for bias within a study. There is currently no ‘gold standard’ quality assessment tool for observational studies [28]. The STROBE Statement covers 22 items covering the whole of the articles from introduction, method, results and discussion, which are important to consider when assessing the quality of observation studies (including cohort, case-control and cross-sectional studies). The adapted version used in this review included 18 items; only the information which is pertinent to quality appraisal of the studies was included. Using Boyle’s recommendations for the evaluation of prevalence studies, the items exclude which were not considered relevant information, such as the title, abstract, background, setting and funding [29].

3. RESULTS OF THE SEARCH

The search results are outlined in Appendix 3. Sixty-four articles (26,321 participants) were included. Of the 64 included studies, none of which were RCTs, 52 were prospective observational studies and 12 were retrospective analyses. Consequently quality of study was assessed using the STROBE checklist. Although none of the studies were RCTs, one study was a retrospective analysis of data from an RCT archive [30]. Studies excluded from this review are outlined in a Appendix 4. Quality appraisal using the adapted STROBE checklist is outlined in a Appendix 5.

Seven of the studies (14,573 participants) reported on overall visual impairment. Nineteen of the studies (17,924 participants) reported on visual field defects; 22 of the studies (4330 participants) reported on ocular alignment and motility defects; nine of the studies (2097 participants) reported on central vision problems; and 13 of the studies (2885 participants) reported on types of perceptual visual deficits following stroke (including visual neglect/inattention, visual hallucinations, agnosia and reduced stereopsis). Several studies reported on two or more of these categories.

None of the studies included had a specific primary aim to calculate either prevalence or incidence of visual impairment following stroke. Fifty five studies were studies specifically investigated visual impairment following stroke, this included studies looking at specific visual problems such as visual inattention. The remaining 16 studies investigated symptoms and signs of stroke, which included reported visual impairment.
4. QUALITY OF THE EVIDENCE

Three papers reported 100% of the items requested by the adapted STROBE checklist [31]. Sixteen papers reported 90% or more of the requested items, 51 papers reported 75% or more. Sixty-one papers reported 50% or more and three papers failed to reach 50%, achieving 17%, 33% and 39% [32-34]. Only 36% of papers reported limitations of their studies. Results from all papers were reported and the individual results for each paper are outlined in a Appendix 5.

5. PREVALENCE AND INCIDENCE

5.1 Visual Impairment

Our search of the literature did not reveal any studies that specifically aimed to assess the incidence of visual impairment following stroke. We identified a number of studies that report an overall figure of prevalence for visual impairment. All these studies, however, were judged to have limitations relating to the methods of recruitment or assessment. Thus a calculation of incidence was not possible and estimates are calculated for prevalence.

Three prospective studies of stroke populations (n=709) report an average prevalence of visual impairment post stroke of 65% ranging from 62-71% (Table 1) [32,33,35]. These studies evaluated a general stroke population including medical and orthoptic assessments undertaken during the acute stroke phase within one week of onset to three months post stroke onset. Further to these three studies of general stroke populations, one prospective study (n=915) recruited a sub population of stroke survivors with suspected visual impairment who received full orthoptic assessment, typically within three weeks of stroke onset [6]. They reported a prevalence of 92% visual impairment. It is unknown what was missed from the general stroke population as not all individuals can report visual symptoms and referrals were evaluated to be more accurate when visual symptoms were taken into consideration in addition to ocular signs in comparison to ocular signs alone [36]. Ali et al., analysed results from a database for stroke survivors recruited to a variety of stroke-related clinical trials and reported a baseline prevalence of 60% visual impairment [30]. This cohort would typically include those who are able and willing to participate in a clinical trial and are therefore, not representative of the whole population, for example individuals with cognitive impairment and aphasia are less likely to be recruited [37].

Three studies (n=13,541) used a stroke assessment tool (NIHSS ± status questionnaire) which only partly assesses visual function [30,31,38]. The National Institute of Health Stroke Scale (NIHSS) is an assessment tool that only assesses for the presence of visual field loss and horizontal gaze problems [39]. Thus it is not a full assessment of the possible visual problems which can manifest as a result of stroke. It can therefore be argued that the numbers presented by these studies are not a true measure of overall incidence of visual impairment following stroke. In addition to the NIHSS, the Questionnaire for Verifying Stroke-free Status (QVSFS) was used. However this questionnaire only asks the patient about painless complete or partial vision loss [40]. The range of overall incidence of visual problems was 19-25.9% from these studies which was considerably less than studies with more comprehensive vision assessment methods.

5.2 Visual Field Loss

The reported prevalence of visual field loss after stroke varies considerably in the literature from 5.5% to 57% (Table 2) and most probably due to its dependence on the type and affected area of a stroke, inclusion criteria and the timing of assessments and the method of testing used [41-44].

Seven studies (n=1210) recruited stroke patients consecutively either as they were admitted to hospital acute stroke units or rehabilitation wards. Assessment of visual fields by confrontation and/or perimetry on admission after stroke onset detected visual field loss in up to 57% [32,33,41,45-48]. The mean prevalence of visual field loss after stroke was calculated as 31% [32,33,41,45-48]. These studies typically assessed patients in the acute phase with homonymous hemianopia or quadrantanopia defects most frequently detected.

In addition to the above studies, seven prospective studies (n=15,388) of stroke sub-populations report prevalence of visual field loss [21,30,43,49-51]. These sub-populations typically include only stroke survivors with hemianopic or quadrantanopic field loss or with suspected visual impairment of any type, or do not recruit consecutively. Thus reported prevalence is not representative of the full stroke population.
Prevalence of visual field loss has been described based on symptom reporting by patients in four studies \((n=1362)\) ranging from 14.6 to 22.7% \([42,52-54]\). These reports are considerably lower and likely reflecting the poor reliability of detection by patient reported symptoms. In addition to those formally diagnosed with visual field loss following stroke, it is important to consider how many patients are unaware of their visual loss. Celesia et al. conducted a prospective observation study \((n=32)\) to investigate the presence of hemianopic anosognosia \([54]\). From a sample of thirty two patients with homonymous visual field loss, 62% were unaware of their visual deficit. In a recent paper it was reported that only 45% of participants with visual field loss reported symptoms of the visual field loss \([36]\). It is important to note that not all patients had isolated visual field loss. Multiple visual impairments caused by stroke were reported such as visual acuity loss, eye movement abnormalities and perceptual difficulties. This discrepancy between those who do not complain of symptoms and have a diagnosis of visual field loss may highlight an under estimation in the incidence in this and other studies.

For studies whose population samples have solely included patients with visual field loss post stroke, it is not possible to establish prevalence. However, several of these studies have shown almost equal numbers suffering right or left defects \([34,44,55,56]\).

### 5.3 Ocular Motility/Strabismus

Three prospective studies \((n=1262)\) reported an average prevalence of all ocular motility problems as 33% (Table 3) with a range from 22% to 54%, \([18,35,57]\). Assessments were usually within the acute period and two studies used detailed orthoptic evaluation of eye movements and binocular vision \([18,35]\). Methods of ocular motility assessment are important to the accuracy of identification of eye movement abnormalities to ensure full detection of deficits in various gaze positions.

#### 5.3.1 Eye alignment

Strabismus may occur as an isolated finding or in association with ocular motility problems and is reported in 16.5% to 52% of stroke survivors recruited to three prospective observation studies \((n=626)\), with an average prevalence of 38% \([32,35,58]\). These studies used validated orthoptic assessments to detect presence of strabismus, increasing their accuracy of detection. In a sub-population prospective multi-centre observational study, 19% of the sample were identified with strabismus \([23]\). Pre-existing strabismus was acknowledged in 2.5%, thus 16.5% were considered to be a direct result of stroke. The cause of the strabismus in 70% of cases was an ocular motility defect. Only 36% were symptomatic with diplopia, which highlights an issue in relying purely on symptoms alone. This study has a risk of under-estimating the prevalence, as the sample is not representative of the whole stroke population.

Diplopia is reported as a symptom in many papers which is a result of a misalignment of the eyes and a disruption of binocular vision. Other studies have highlighted the discrepancy between patients who do or do not report diplopia in the presence of strabismus or ocular motility defects. There is a risk that a proportion is not captured, if the symptom of diplopia is relied upon to identify ocular motility defects. The majority of studies reporting the incidence of diplopia limit recruitment to include strokes affecting specific areas of the brain \([43,59,60]\), are retrospective \([42,53]\) or required informed consent \([61]\). These studies cannot be generalised to the whole stroke population and also carry a risk of under estimating the true prevalence of strabismus.

#### 5.3.2 Eye movement palsy

Seven studies \((n=2783)\) report figures for gaze palsies including horizontal and/or vertical gaze positions and have a mean prevalence following stroke of 26% (range 18-44%) \([22,32,35,43,57,62,63]\). These defects may occur in isolation or in conjunction with other visual problems, and are the most common of all ocular motility abnormalities \([22,57]\). Horizontal gaze palsies are more prevalent than vertical and complete palsies more prevalence than partial \([22,32,35,63]\).

Cranial nerve palsies affecting the ocular motor muscles include third, fourth and sixth nerves with a mean post-stroke prevalence of 16% (range 3 to 39%) from three studies \((n=2329)\) \([18,32,43,57]\). Third nerve and sixth nerve palsies are reported as being more prevalent than fourth nerve palsies in these stroke populations \([18,32,64]\). Where ocular movement assessment only tests horizontal gaze (such as with the NIHSS screening tool) the
identification of all ocular cranial nerve palsies is limited. It is likely that more subtle nerve palsies and those involving the vertical muscles may be missed.

### 5.3.3 Nystagmus

Following stroke, nystagmus is reported in an average of 11% (range 4 to 48%) in three studies (n=438) [35,62,65]. In most prospective and retrospective studies reporting nystagmus, the specific types of nystagmus are not reported. This, in addition to lack of information regarding the method of assessment, makes it difficult to assess if the more subtle types, or nystagmus not present in primary position, have been missed. These factors increase the risk of an underestimation of prevalence. When reported, common types of acquired nystagmus are gaze evoked, multi-vector and upbeat [66]. No studies have reported the prevalence of nystagmus in anterior circulation strokes in isolation. It is, therefore, not possible to estimate the proportion of cases which are potentially missed by restricting populations to posterior circulation strokes only.

### 5.3.4 Vergence

Clisby (n=140) reported 55% of patients to have reduced convergence and/or stereopsis [32]. Rowe et al. (n=243) reported reduced convergence from the initial ten month data set of the Vision in Stroke (VIS) study [69]. Using the gold standard ‘normal’ attainment for convergence of 6cm, 54% were judged to have reduced convergence. However, they also reported that 26% had convergence reduced less than 10cm, which could be judged to be a more appropriate standard for an older group of patients. Siong et al. reported 21% of the recruited population to have convergence reduced less than 15 cm [61].

### 5.4 Visual Acuity and Central Vision Deficit

Clinical assessment of visual acuity has been used to identify those with reduced vision and up to 70% of stroke survivors (Table 4) have been noted to have poor central vision [32,36,64,70]. The mean prevalence of reduced visual acuity post-stroke was calculated from three studies (n=270) as 53% [32,64,70]. Methods include visual acuity assessment at near, a 3 or 6 metre distance. Further retrospective studies (n=447) provide information on the prevalence of patients reporting symptoms associated with a reduction of visual acuity [42,53]. A key issue identified by three studies (n=1045) related to patient glasses [36,64,70]. These were frequently reported as missing, or the glasses present were dirty, broken or the wrong prescription.

An important component of central visual function is contrast sensitivity, the reduction of which can deform image perception. Contrast sensitivity function has been reported to be abnormal in 62% of stroke patients (n=16) [71]. Different areas of the spectrum are impaired depending on the lesion site. For example, participants with parietal and temporal lesions have been reported to have reduced detection of low spatial frequencies whereas those with occipital and occipito-temporal lesions had difficulty with medium to high spatial frequencies [71]. Furthermore, reduced contrast sensitivity in stroke survivors, particularly those with severe functional difficulties, has been found to be associated with reduced activities of daily living [72].

Central vision is key to activities such as reading. However, reading difficulties may be caused by a wide range of visual impairments in addition to reduced visual acuity. Rowe et al. (n=915) reported difficulties with reading occurred in 19.3% of the sample [19]. The three largest associations with reading difficulties were visual field loss (61.6%, the majority of which were complete homonymous hemianopia), reduced convergence of less than 6 cm (45.8%) and saccadic abnormalities (45.0%). Other visual impairments associated with reading difficulties included reduced visual acuity (22.5%), perceptual deficits (22%), including 16.5% with visual inattention, nystagmus (12.4%) and diplopia (8.5%).

### 5.5 Visual Perception Abnormalities

The commonest form of visual perception disorder following stroke is visual neglect or inattention. The literature reporting the prevalence of visual neglect/inattention can be difficult to interpret. Often the different types of inattention (e.g. auditory, visual, and spatial) are not separated, so it is not always possible to isolate visual inattention.
### Table 1. Overall visual impairment prevalence

| Study                  | Design             | Population                  | Time of vision assessment | Sample size (n=) | Prevalence of visual issue (%) | Co-existent ocular condition | Method of visual assessment |
|------------------------|--------------------|-----------------------------|---------------------------|-----------------|-------------------------------|-----------------------------|-----------------------------|
| 1974; Isaeff et al. [33]| Prospective        | General stroke              | Median within 3 months of onset | 322             | 62                            | Yes                         | Medical                     |
| 1987; Freeman & Rudge [35] | Prospective        | General stroke              | Median within 1 week of onset | 247             | 63                            | Yes                         | Medical                     |
| 1995; Clisby [32]      | Prospective        | General stroke              | Acute period on stroke unit | 140             | 71                            | Yes                         | Orthoptic                   |
| 2007; Barrett et al. [38]| Prospective        | General stroke              | Unknown                   | 505             | 19                            | Unknown                     | NIHSS and Questionnaire for verifying stroke-free status |
| 2009; Rowe et al. [6]  | Prospective        | Stroke survivors with suspected visual issues | Median within 3 weeks of onset | 323             | 92                            | Yes                         | Orthoptic                   |
| 2013; Ali et al. [30]  | Trial data         | Acute stroke                | Median within 1 week of stroke onset | 11900           | 60                            | Unknown                     | NIHSS                       |
| 2010; Gall et al. [31] | Retrospective      | General stroke              | Unknown                   | 1136            | 25.9                          | 23–male, 29–female           | NIHSS                       |

### Table 2. Visual field loss prevalence

| Study                  | Design             | Population                  | Time of vision assessment | Sample size (n=) | Prevalence of visual issue (%) | Co-existent ocular condition | Method of visual field assessment |
|------------------------|--------------------|-----------------------------|---------------------------|-----------------|-------------------------------|-----------------------------|---------------------------------|
| 1973; Haerer et al. [47]| Prospective        | General stroke              | Unknown                   | 265             | 25 – homonymous hemianopia/ quadrantanopia | Unknown                     | Confrontation                   |
| 1974; Isaeff et al. [33]| Prospective        | General stroke              | Median within 3 months of onset | 322             | 17 – visual field loss         | Ocular pathology            | Confrontation                   |
| 1989; Gray             | Prospective        | General stroke              | Followed every 24 hours for 4 days | 174             | 56.9 – homonymous hemianopia   | Ocular pathology            | Confrontation                   |
| Study | Design | Population | Time of vision assessment | Sample size (n=) | Prevalence of visual issue (%) | Co-existent ocular condition | Method of visual field assessment |
|-------|--------|------------|---------------------------|------------------|-------------------------------|-----------------------------|-------------------------------|
| et al. [41] | Prospective observation | General stroke | and max to 28 days | 94 | 46.6 – hemianopia 10.3 – quadrantanopia | Unknown | Unknown |
| 1993; Benedetti et al. [48] | Prospective observation | General stroke | Median within 48 hours of admission | 19.1 – homonymous hemianopia | Unknown | Unknown |
| 1995; Clisby [32] | Prospective observation | General stroke | Acute period on stroke unit | 47 – visual field loss | Ocular pathology | Confrontation Campimetry |
| 1997; Agrell et al. [45] | Prospective observation | General stroke | Median within 3 months of onset | 30 – homonymous hemianopia | Visual inattention | Confrontation |
| 1997; Celesia et al. [54] | Prospective observation | Stroke survivors with hemianopia | Median within 24 hours of onset | 100 – homonymous hemianopia 62 – asymptomatic | Unknown | Kinetic perimetry |
| 2000; Lotery et al. [64] | Prospective observation | General stroke | Median within 3 months of onset | 19.5 – visual field loss ¾ hemianopia 1/2 asymptomatic | Ocular pathology | Unknown |
| 2001; Cassidy et al. [46] | Prospective observation | General stroke | Median within 3 months of onset | 50.6 - visual field loss | Ocular pathology | Confrontation Perimetry |
| 2007; Townsend et al. [51] | Prospective observation | General stroke excluding receptive aphasia and cognitive impairment | Within 9 months of onset | 16 – homonymous hemianopia | Unknown | Static perimetry |
| 2009; Rowe et al. [6] | Prospective observation | Stroke survivors with suspected visual issues | Median within 3 weeks of onset | 49.5 – visual field loss ¾ hemianopia 1/2 asymptomatic | Ocular pathology Visual inattention | Confrontation Kinetic perimetry Static perimetry |
| 2012; Tao et al. [43] | Prospective observation | General stroke: anterior vs posterior circulation | Median within 3 months of onset | 6.9 – visual field loss Hemianopia: 4.3 – posterior circulation 1.3 – anterior circulation Quadrantanopia:1.3 – posterior circulation | Unknown | NIHSS Confrontation |
| Study | Design | Population | Time of vision assessment | Sample size (n=) | Prevalence of visual issue (%) | Co-existent ocular condition | Method of visual field assessment |
|-------|--------|------------|---------------------------|-----------------|--------------------------------|-----------------------------|----------------------------------|
| 2013; Ali et al. [30] | Prospective trial data | General stroke | Median within 1 week of stroke onset | 11900 | 51 – visual field loss: majority hemianopia | Unknown | NIHSS Confrontation |
| 2013; Rowe et al. [21] | Prospective | Stroke survivors with suspected visual impairment | Variable over 2 weeks to 6 months | 915 | 52.3 – visual field loss 54 – complete homonymous hemianopia 19.5 – partial homonymous hemianopia 15.2-homonymous quadrantanopia 0.2 – temporal crescent 9.2– constricted fields 5.1 – scotomas 1.7 – bilateral hemianopia | Yes | Confrontation Static perimetry Kinetic perimetry |
| 2014; Siong et al. [61] | Prospective observation | General stroke | 10 days to 26 years post stroke onset | 113 | 26.5 – monocular defects 11.5 – binocular defect | Ocular pathology | Confrontation |
| 2001; Lawrence et al. [49] | Retrospective | Stroke register | Median within 3 months of onset | 1136 | 26.1 – visual field loss | Unknown | Unknown |
| 2002; Rathore et al. [52] | Retrospective | Database stroke cohort | Unknown | 474 | 14.6 – homonymous hemianopia | Unknown | Unknown |
| 2005; Ng et al. [50] | Retrospective | Posterior circulation strokes | Unknown | 89 | 53 – visual field loss | Unknown | Unknown |
| 2011; Jerath et al. [53] | Retrospective | General stroke Male vs female | Unknown | 449 | 22.7 – visual field loss (female) 20.9 – visual field loss (male) | Unknown | Neurology Accident & Emergency assessment Non-standardised |
| 2012; Searls et al. [42] | Retrospective | Posterior circulation stroke | Unknown | 407 | 22 – visual field loss | Unknown | Neurology assessment of signs and symptoms |
### Table 3. Eye movement disorder prevalence

| Study                  | Design                      | Population         | Time of vision assessment | Sample size (n=) | Prevalence of visual issue (%)                                                                 | Co-existent ocular condition | Method of assessment |
|------------------------|-----------------------------|--------------------|---------------------------|-----------------|------------------------------------------------------------------------------------------------|-----------------------------|---------------------|
| 1975; Yap et al. [57]  | Prospective observation     | General stroke     | Median within 2 days of onset | 100             | 44 – ocular motility disorders<br>28 – gaze palsy<br>11 – impaired VOR<br>6 – cranial nerve palsy | Unknown                    | Unknown             |
| 1982; De Renzi et al. [62] | Prospective observation     | General stroke     | Follow-up every 3-4 days for 2 weeks post onset | 91              | 28 – horizontal gaze palsy<br>7 - nystagmus                                                                 | Unknown                    | NIHSS               |
| 1987; Freeman & Rudge [35] | Prospective observation     | General stroke     | Median within 1 week of onset | 247             | 22 – ocular motility disorders<br>35 – strabismus (additional 6% pre-existent)<br>18 – palsies<br>(skew deviation:3<br>1 ½ syndrome 6<br>Horizontal gaze palsy 57%<br>Vertical gaze palsy 20%)<br>23 - nystagmus | Yes                        | Medical Orthoptic   |
| 1995; Clisby [32]      | Prospective observation     | General stroke     | Acute period on stroke unit | 140             | 52 – strabismus<br>44 – gaze palsy:<br>90 – horizontal with right hemisphere stroke<br>73 – horizontal with left hemisphere stroke<br>39 – cranial nerve palsy (mainly III)<br>55- reduced vergence and stereoaucity | Ocular pathology           | Orthoptic           |
| 1996; Fowler et al. [58] | Prospective observation     | Mixed neurological on | Median within 2 months of stroke | 239 (54% stroke) | 26 – stroke-related strabismus                                                                 | Unknown                    | Orthoptic           |
| Study               | Design                  | Population                                            | Time of vision assessment | Sample size (n=) | Prevalence of visual issue (%) | Co-existent ocular condition | Method of assessment       |
|---------------------|-------------------------|-------------------------------------------------------|---------------------------|-----------------|-------------------------------|------------------------------|-----------------------------|
|                     |                         | rehabilitation unit admission                         |                           |                 |                               |                              |                             |
| 2000; Lotery et al. [64] | Prospective observation | General stroke                                        | Median within 2 weeks of onset | 77              | 2.6 – third nerve palsy       | Yes                          | Ophthalmology and optometric |
| 2006; Singer et al. [63] | Prospective             | Sub population excluding haemorrhagic stroke and posterior circulation ischaemia | Within 6 hours of onset | 116             | 26.7 – complete gaze palsy    | 0.6 – partial gaze palsy     |                             |
| 2007; Rowe et al. [70]       | Prospective observation | Stroke survivors with suspected visual impairment     | Median within 3 weeks of onset | 243             | 54 – reduced convergence <6cms. 28 – reduced convergence <10cms. | Yes                          | Orthoptic                   |
| 2008; Rowe et al. [66]       | Prospective observation | Stroke survivors with suspected visual impairment     | Median within 3 weeks of onset | 323             | 12 – nystagmusN=2 – pre-existentN=18 – oscillopsia/vertigo symptoms | Yes                          | Orthoptic                   |
| 2009; Siddique et al. [65]   | Prospective             | General stroke                                        | Acute period              | 100             | 4 - nystagmus                 | Unknown                      | Unspecified protocol         |
| 2009; Akhtar et al. [68]     | Prospective             | Posterior circulation stroke only                     | Acute period              | 116             | 48 – nystagmus                | Unknown                      | Unknown                     |
| 2009; Rowe et al. [24]      | Prospective observation | Stroke survivors with suspected visual impairment     | Median within 3 weeks of onset | 323             | 54 – reduced convergence <6cms 26 – reduced convergence <10cms | Yes                          | Orthoptic                   |
| 2010; Rowe et al. [23]      | Prospective observation | Stroke survivors with suspected visual impairment     | Median within 3 weeks of onset | 512             | 19 – strabismus 16.5 – new onset 2.5 – pre-existent | Yes                          | Orthoptic                   |
| 2011; Rowe et al.           | Prospective observation | Stroke survivors with suspected visual impairment     | Median within 3 weeks of onset | 915              | 54 – ocular motility disorders | Yes                          | Orthoptic                   |
| Study | Design                | Population                      | Time of vision assessment | Sample size (n=) | Prevalence of visual issue (%) | Co-existent ocular condition | Method of assessment |
|-------|-----------------------|---------------------------------|---------------------------|-----------------|-------------------------------|----------------------------|---------------------|
| [18, 19] |                       | visual impairment               |                           |                 | 2/3 – diplopia 19 – strabismus (2.5% pre-existent) 10 – cranial nerve palsy (VI>III>IV) 58 – VI 26 - III |                             |                     |
| 2011; Baier & Dieterich [67] | Prospective               | Cerebellar stroke              | Mean within 6 days        | 21              | 33 – nystagmus                 | Unknown                   | Eye movement recording |
| 2012; Maeshima et al. [59] | Prospective observation   | Pontine stroke                 | Unknown                   | 68              | 15.9 – diplopia                | Unknown                   | Unknown             |
| 2012; Tao et al. [43] | Prospective observation   | General stroke: Anterior vs posterior circulation stroke | Acute period              | 1174            | 8 – diplopia: 7.3 posterior circulation 0.7 anterior circulation 13.5 – gaze palsy: 11 – anterior circulation 2.6 – posterior circulation 4 – cranial nerve palsy: posterior circulation | Unknown                   | NIHSS               |
| 2013; Su & Young [60] | Prospective observation   | Posterior fossa stroke: vertigo clinic | Unknown                   | 70              | 31 – ocular motility disorders 45 – diplopia N=22 – nystagmus [45.5% multidirectional 54.5 unidirectional 86 - reduced OKN] | Unknown                   | Nystagmus – eye movement recordings |
| 2013; Rowe et al. [22] | Prospective observation   | Stroke survivors with suspected visual impairment | Median within 3 weeks of onset | 915             | 23 – gaze defect: 15.9 – horizontal and vertical gaze palsy 69.7 – complete 13.5 – saccadic palsy 22.2 – smooth pursuit | Yes                       | Orthoptic           |
| Study                        | Design                | Population                  | Time of vision assessment | Sample size (n=) | Prevalence of visual issue (%)                                      | Co-existent ocular condition | Method of assessment                           |
|------------------------------|-----------------------|-----------------------------|---------------------------|-----------------|---------------------------------------------------------------------|-----------------------------|-----------------------------------------------|
| 2014; Siong et al. [61]      | Prospective observation | General stroke              | 10 days to 26 years post stroke onset | 113             | 53.1 – jerky eye movements, 11.5 – restricted ocular motility, 20 – reduced convergence (<15cm) | Yes                         | Optometrist                                   |
| 2011; Jerath et al. [53]     | Retrospective         | General stroke Male vs female | Unknown                   | 449             | 7.8 – diplopia (7.1% male, 0.7% female), 17.5 – nystagmus (4.6 male, 12.9 female) | Unknown                     | Neurology Accident & Emergency assessment Non-standardised |
| 2012; Searls et al. [42]     | Retrospective         | Posterior circulation stroke | Unknown                   | 407             | 20 – ocular motility disorders, 15 – diplopia, 25 – nystagmus       | Unknown                     | Neurology assessment of signs and symptoms    |
### Table 4. Central visual deficit prevalence

| Study                        | Design                      | Population                                | Time of vision assessment | Sample size (n=) | Prevalence of visual issue (%) | Co-existent ocular condition | Method of assessment                  |
|------------------------------|-----------------------------|-------------------------------------------|---------------------------|-----------------|--------------------------------|-------------------------------|--------------------------------------|
| 1989; Bulens et al. [71]     | Prospective observation     | General stroke                           | Days to years post onset  | 16              | 62 – reduced contrast sensitivity | No                            | Ophthalmology                       |
| 1995; Clisby [32]            | Prospective observation     | General stroke                           | Acute period on stroke unit | 140             | 58 – reduced visual acuity      | Excluded ocular pathology       | Orthoptic with adapted visual acuity assessment for dysphasia |
| 2000; Lottery et al. [64]    | Prospective observation     | General stroke                           | Median within 2 weeks of onset | 77              | 30 – visual acuity ≤6/12 27 – no glasses available, dirty or damaged lenses | Yes                           | Ophthalmology and optometric          |
| 2006; Edwards et al. [70]    | Prospective observation     | General stroke with exclusions if unable to hold a pencil or severe motor or language deficits | Median within 15 days of onset | 53              | 70 – reduced visual acuity 30 – 6/7.5-6/15 4 – 6/21-6/30 36 – 6/60-6/120 54 – no glasses available | Unknown                         | Near visual acuity                   |
| 2011; Rowe et al. [19]       | Prospective observation     | Stroke survivors with suspected visual impairment | Median within 3 weeks of onset | 915             | 19.3 – reading impairment: 61.6 – field loss 45.8 – reduced convergence 45 – saccadic defects 22.5 – reduced visual acuity 22 – perceptual defect | Yes                           | Orthoptic                           |
| 2013a; Rowe et al. [36]      | Prospective observation     | Stroke survivors with suspected visual impairment | Median within 3 weeks of onset | 915             | 31 – reduced visual acuity      | Yes                           | Orthoptic                           |
| Study | Design            | Population                                      | Time of vision assessment | Sample size (n=) | Prevalence of visual issue (%) | Co-existent ocular condition | Method of assessment                  |
|-------|-------------------|-------------------------------------------------|---------------------------|-----------------|-------------------------------|-------------------------------|--------------------------------------|
| 2011: Jerath et al. [53] | Retrospective     | General stroke Male vs female                   | Unknown                   | 449             | 27 – loss of vision reported: 15.8 – male 10.3 - female 19 – visual disturbance reported: blurred vision, focus difficulty, photophobia, visual hallucinations | Unknown                       | Neurology Accident & Emergency assessment Non-standardised |
| 2012: Searls et al. [42] | Retrospective     | Posterior circulation stroke                    | Unknown                   | 407             | 20 – blurred vision           | Unknown                       | Neurology assessment of signs and symptoms |
| 2012: dos Santos & Andrade [72] | Retrospective     | General stroke with haemorrhagic stroke excluded | 40                         |                 | 100 – reduced contrast in comparison to controls | Excluded ocular pathology | Ophthalmology                        |
| 2014: Siong et al. [61] | Prospective observation | General stroke 10 days to 26 years post stroke onset | 113                        | 29.8 – vision worse than 0.3 LogMAR 11.5 – mild reduced vision (worse than 0.5 LogMAR) 1.8 – moderate reduced vision (worse than 1.0 LogMAR) | Yes                           | Optometrist                          |
Visual inattention has been reported on average in 32% (range 14% to 82%) (Table 5) of stroke survivors from five studies (n=1800) [56,73-76]. These studies have recruited participants consecutively and have used a range of tests or tools for visual inattention including cancellation tests and the Behavioural Inattention Test. Studies (n=1335) using cancellation tests alone reported prevalence of 15% to 26% [73,75,77]. Those using a variety of assessments (n=991) for visual inattention reported a prevalence of 14% to 82% [56,74,78-81]. Discrepancies in the wide range of prevalence figures typically related to the timing of assessment plus inclusion/exclusion criteria of left versus right sided stroke lesions and severe cognitive and/or communication deficits. As expected, there was a greater prevalence of left versus right sided inattention.

In addition to visual neglect/inattention, the prevalence of other perceptual deficits are reported in the literature. Perceptual deficits, such as object agnosia, colour detection difficulties have been reported in the literature in very small numbers [19,23,24,81]. Our literature search found four studies reporting an estimated prevalence for different visual perceptual deficits following stroke [24]. Beaudoin et al. (n=189) reported an overall prevalence of visual perception deficits as 49.2% [82]. Rowe et al. (n=323) estimated the prevalence as 20%, of which the prevalence of visual hallucinations after stroke was 4% and visual agnosia was 2.5% [24]. It was reported that patients with visual hallucinations and other perceptual deficits frequently do not disclose these symptoms. This, in addition to the method of recruitment could result in an under-estimation of the true prevalence. Yang et al. (n=82) reported 50% of participants had pathologic (>3º) subjective visual vertical tilt following brainstem stroke [83]. Chechlacz et al. (n=454) reported 28% of participants with right hemisphere stroke showed left visual extinction versus 6.8% of participants with left hemisphere stroke showed right visual extinction [84].

Freeman and Rudge reported 79% of participants to have defective stereopsis [35]. Stereopsis was only tested in the pilot study (n=26), therefore the number of participants tested was limited to 19. It was also purposely not tested on participants with manifest strabismus even those which were a direct result of the stroke. The majority of those with strabismus would not demonstrate any stereopsis. This would result in an underestimation of those suffering reduced or absent stereopsis as a direct result of stroke.

6. RECOVERY OF VISUAL FUNCTION

Our literature search identified just one study that appears to report the recovery of overall visual problems following stroke (Table 6). The majority that report recovery do so for visual field loss (Table 7). Ali et al. had the largest sample for tracking recovery of multiple visual problems following stroke [30]. However, not all visual problems were included due to the use of the NIHSS which limits assessment to visual field loss and horizontal gaze paresis. There was a variable sample size at the three time points used (baseline, 30 days and 90 days post stroke). The authors reported a reduction of visual problems to 28.2% at 30 days and a further reduction to 20.5% at 90 days, compared to the initial 60.5% at baseline. The sample size considerably decreased between baseline (n=11,900) to 30 days post stroke (n=4,965).

6.1 Visual Field Loss

Recovery of visual field loss is reported by a number of studies but across variable time periods (Table 7). The percentage of patients recovering from visual field loss ranges from 0% to 44% for complete recovery and up to 72.2% for partial recovery (n=6656) [30,35,41,46,55,85-87]. Variability in recovery rates appears to be dependent on time of baseline assessment and length of follow-up, accuracy of visual field assessment methods and their sensitivity to detection of change, prospective versus retrospective studies and exclusions of severe neurological and communication defects.

Gray et al. (n=174) documented recovery in 47.8% of their sample, with a slightly higher proportion of 56.5% who had suffered a right hemianopia [41]. The macula was involved in 56.3% of the sample; 72.2% seeing an improvement in this and surrounding areas. They noted four different patterns of recovery, the most common (34.4%) of which was recovery of the lower quadrant. This was followed by complete recovery (25%), recovery of the upper quadrant (21.9%) and finally improvement in both quadrants with some residual defect (18.7%). They found that most improvement occurred between 6 and 25 days post stroke. Cassidy et al. (n=19) reported that of those patients who demonstrated some recovery, only 15.8%
achieved complete recovery at four weeks [46]. The majority of 42.1% had some central recovery and the remainder had quadrantic recovery. For a patient with complete homonymous hemianopia the recovery of the macula area can appear to be only a small recovery. However, this can have a considerable functional impact such as with reading ability. They were also able to demonstrate the reduced sensitivity of the confrontation method at detecting areas of recovery. Variances in reports related to whether the baseline visual field loss was complete or partial and/or congruous versus incongruous loss along with stroke-specific or mixed populations.

6.2 Ocular Motility Abnormalities and Strabismus

Less has been reported on the recovery of ocular alignment and motility problems following a stroke (Table 8). The percentage of patients which were reported to recover ranged from 7% to 28.5% for full recovery and up to 92% for partial recovery (n=6047) [18,22,30,35,62,66]. The greatest recovery was for reduced stereoacuity at 92% [35]. Sixth nerve palsies were reported to have the highest incidence of complete recovery of cranial nerve palsies at 28.5% [18]. At least one third showed no recovery across ocular motility conditions of gaze palsy, nystagmus, cranial nerve palsy and strabismus [18,19,35,66].

6.3 Visual Acuity and Central Vision Deficit

Little is reported on the recovery of vision following stroke (Table 9). We found one study (n=247) that outlined the recovery of reduced vision following stroke [35]. The majority (71%) showed some recovery. It is not clear from this paper what extent of recovery was made and whether this had been achieved at the one or six month follow-up.

Rowe et al. (n=915) reported the recovery rates for a group of participants suffering reading difficulties [19]. The data from follow-up visits was available for 42.9% of the participants. Of these, 10.5% had complete resolution of their symptoms, and 43.4% showed some improvement. A similar proportion of 44.7% saw no change in their symptoms and only 1.3% experienced deterioration in their condition.

6.4 Visual Perception abnormalities

6.4.1 Visual inattention

Four studies (n=5286) have reported recovery of visual neglect/inattention [30,35,79,88]. The percentage of recovery reported in the literature ranges from 29% to 78% (Table 10). In contrast to other visual impairments, patients suffering with visual neglect were more likely to require a longer stay in hospital and have a poorer prognosis for recovering function [73]. Recovery is mostly seen within 3 months post onset [30,35,79] with approximately 10% full recovery within the first 2 weeks [90].

6.4.2 Other perceptual deficits

One study (n=140) was found to report the recovery of visual hallucinations [89]. The authors reported that visual hallucinations (Charles Bonnet syndrome) persisted for several days or weeks after the onset of stroke before gradually subsiding. The median duration of visual hallucinations was 28 days and they stated that the first 90 days is when spontaneous recovery is most likely to occur.

7. LIMITATIONS AND RECOMMENDATIONS FOR FUTURE INCIDENCE, PREVALENCE AND RECOVERY STUDIES

None of the studies provided information about stroke survivors who were not admitted to a stroke unit/ward/rehabilitation unit. It is acknowledged that a proportion of stroke survivors have visual impairment only (usually occipital infarcts) but the numbers of these remain unknown.

The time of visual examination post stroke has a direct effect on the estimate of prevalence of visual problems that occur due to stroke. As recovery of visual conditions can occur rapidly in some cases during the first weeks post stroke, studies that assess visual function later than this early two week period are likely to detect those with persistent visual impairment. The extent of visual impairment for those with persistent visual conditions may also be misrepresented as these individuals may have had substantial improvement with only partial deficits remaining. Thus there is considerable potential for an underestimation of stroke related visual impairment.
Table 5. Visual perceptual impairment prevalence

| Study | Design | Population | Time of vision assessment | Sample size (n=) | Prevalence of visual issue (%) | Co-existent ocular condition | Method of assessment |
|-------|--------|------------|---------------------------|-----------------|-------------------------------|-----------------------------|---------------------|
| 1987; Freeman & Rudge [35] | Prospective observation | General stroke | Median within 1 week of onset | 247 | 79 – reduced stereoaucity | Yes | Orthoptic |
| 1993; Stone et al. [56] | Prospective | General stroke | Median within 3 days of onset | 171 | 82 – visual neglect [right hemisphere] 65 – visual neglect [left hemisphere] 28 – anosognosia [right hemisphere] 5 – anosognosia [left hemisphere] | Unknown | Modified behavioural inattention test |
| 1997; Pedersen et al. [73] | Prospective | General stroke | At admission | 1014 | 23 – visual neglect [42 – right hemisphere, 8 – left hemisphere] | Unknown | Cancellation tasks |
| 1998; Cassidy et al. [79] | Prospective | General stroke with left hemisphere lesions excluded | Within 7 days and monthly follow-up | 66 | 40.9 – visual neglect 74 – visual field loss | Unknown | Behavioural inattention test |
| 1999; Cassidy et al. [80] | Prospective | General stroke with left hemisphere lesions excluded | Within 7 days and monthly follow-up | 44 | 61.4 – visual neglect | Unknown | Behavioural inattention test |
| 2002; Appleros et al. [74] | Prospective retrospective cases | General stroke | Unknown | 279 | 23 – visual neglect [62 – right hemisphere] 74 – anosognosia | Unknown | Test battery |
| 2006; Linden et al. [75] | Prospective | General stroke | At 20 months of onset | 243 | 15 – visual neglect | Unknown | Star cancellation |
| 2007; Becker & Karnath [76] | Prospective | General stroke | Median within 3 days of onset | 93 | 26.2 – visual neglect [right hemisphere] 24.3 – visual extinction | Unknown | Cancellation tasks |
| Study                  | Design                  | Population                                      | Time of vision assessment | Sample size (n=) | Prevalence of visual issue (%) | Co-existent ocular condition | Method of assessment          |
|------------------------|-------------------------|-------------------------------------------------|---------------------------|------------------|-------------------------------|------------------------------|-----------------------------|
|                        |                         |                                                  |                           |                  |                               |                              |                             |
| 2009; Lee et al. [78]  | Prospective             | General stroke                                  | Median within 2 months of onset | 138              | 58 – visual neglect           | Unknown                      | Test battery                |
|                        |                         | Left hemisphere excluded                         |                           |                  | 4.9 – visual extinction       |                              |                             |
|                        |                         |                                                  |                           |                  |                               |                              |                             |
| 2009; van Nes et al. [77] | Prospective           | General stroke                                  | Median within 2 weeks of onset | 78               | 21.8 – visual neglect         | Gaze paresis excluded        | Cancellation tasks          |
|                        |                         | Excluded aphasia, gaze palsy, cognitive issues  |                           |                  | 88 – right hemisphere         |                              |                             |
| 2009; Rowe et al. [6,24] | Prospective           | Stroke survivors with suspected visual defect   | Median within 3 weeks of onset | 323              | 14 – visual neglect           | Yes                          | Test battery                |
|                        |                         |                                                  |                           |                  | 4 – visual hallucinations     |                              |                             |
|                        |                         |                                                  |                           |                  | 2.5 – visual agnosia          |                              |                             |
| 2013; Beaudoin et al. [82] | Prospective longitudinal | General stroke                                  | At discharge to home      | 189              | 49.2 – visual perceptual defect | Unknown                      | Motor-free visual perceptual test-vertical version |
|                        |                         |                                                  |                           |                  |                               |                              |                             |
| 2014; Chechlacz et al. [84] | Prospective observational | Sub-acute stroke                               | 2.5 – 27.3 days           | 454              | 9.1 – left visual extinction  | Unknown                      | Confrontation extinction    |
|                        |                         |                                                  |                           |                  | 4.6 right visual extinction   |                              |                             |
| 2014; Siong et al. [61] | Prospective observational | General stroke                                  | 10 days to 26 years post stroke onset | 113              | 5.3 visual neglect            | Yes                          | Line bisection              |
| 2014; Yang et al. [83]  | Prospective observational | Brainstem infarction                             | Less than 10 days post symptom onset | 82               | 50 – pathologic subjective visual vertical tilt (>3º) | Unknown                      | Computerised assessment      |
|                        |                         |                                                  |                           |                  | 76 – ipsiversive              |                              |                             |
|                        |                         |                                                  |                           |                  | 24 – contraversive            |                              |                             |
|                        |                         |                                                  |                           |                  | 54.7 – abnormal torsion       |                              |                             |
### Table 6. Recovery of visual impairment

| Study | Design | Population | Time of vision assessment | Sample size (n=) | Prevalence of visual issue (%) | Assessment |
|-------|--------|------------|---------------------------|-----------------|--------------------------------|------------|
| 2013; Ali et al. [30] | Prospective Stroke trial database | Baseline, 30 days and 90 days | 11900 at baseline 4965 at follow-up | 28.2 – visual impairment at 30 days 20.5 – visual impairment at 90 days Versus 60.6 at baseline | NIHSS |

### Table 7. Recovery of visual field loss

| Study | Design | Population | Time of vision assessment | Sample size (n=) | Prevalence of visual issue (%) | Assessment |
|-------|--------|------------|---------------------------|-----------------|--------------------------------|------------|
| 1987; Freeman & Rudge [35]; 1989; Gray et al. [41]; 1991; Tiel & Kolmel [85]; 2001; Cassidy et | Prospective General stroke | Followed every 24 hours for 4 days and max to 28 days | 247 | 33 – improvement (22 full, 11 partial) 25 – stable field | Confrontation |
| | | | | | | |
| 1987; Freeman & Rudge [35]; 1989; Gray et al. [41]; 1991; Tiel & Kolmel [85]; 2001; Cassidy et | Prospective General stroke | Mean 73 day follow-up1 week to 6 months | 174 | Complete hemianopia: 17 – full resolution within 2-10 days 27 – partial improvement 39 – stable field Partial hemianopia: 44 – full resolution within 48 hours 28 – full resolution within 14 days 17 – stable field | Confrontation |
| | | | | | | |
| 1991; Tiel & Kolmel [85] | Prospective Posterior circulation stroke Excluded communication difficulty and severe neurological deficits | Daily follow-up within 3 weeks of onset | 125 | 47.8 – improvement within 6-25 days 56.5 for right hemianopia 56.3 – macula involved with 72.2 improvement of this 34.4 – recovery of lower quadrant 25 – full recovery 21.9 – recovery of upper quadrant 18.7 – partial recovery | Confrontation |
| | | | | | | |
| 2001; Cassidy et | Prospective General stroke | 4 week intervals up to 12 weeks | 19 | 15.8 – full recovery at 4 weeks 42.1 – central recovery | Perimetry |
| Study                           | Design            | Population       | Time of vision assessment                  | Sample size (n=)                  | Prevalence of visual issue (%) | Assessment                      |
|--------------------------------|-------------------|------------------|--------------------------------------------|-----------------------------------|--------------------------------|---------------------------------|
| 2013; Ali et al. [30]          | Prospective       | Stroke trial     | Baseline, 30 days and 90 days              | 11900 at baseline 4965 at follow-up | Complete hemianopia:            | NIHSS Confrontation             |
|                                |                   | database         |                                             |                                   | 13 at 30 days 10 at 90 days     |                                 |
|                                |                   |                  |                                             |                                   | Versus 35% at baseline Partial hemianopia: |                                 |
|                                |                   |                  |                                             |                                   | 11 at 90 days                   |                                 |
|                                |                   |                  |                                             |                                   | Versus 14.5% at baseline        |                                 |
| 2006; Zhang et al. [87]        | Retrospective     | Mixed population | Median 3 months of onset Change at 3 and 6 months | 254                               | 3 – full recovery 34 – partial | Perimetry Central 30 or 24 degrees |
|                                |                   |                  |                                             |                                   | 63 – stable field               |                                 |
| 2007; Schmielau & Wong [86]    | Prospective       | Mixed population | Change at 1 through to 105 months post onset | 20                                | 61.5 – improvement              | Kinetic perimetry               |
| 2007; Kedar et al. [55]        | Retrospective     | Mixed population | Median 3 days post onset                    | 852                               | Congruous hemianopia:           | Perimetry Central 30 or 24 degrees |
|                                |                   |                  |                                             |                                   | 38.1 – improvement 58.5 – stable field |                                 |
|                                |                   |                  |                                             |                                   | 3.4 – deteriorated Incongruous hemianopia: |                                 |
|                                |                   |                  |                                             |                                   | 39.6 – improvement 41.5 – stable field |                                 |
|                                |                   |                  |                                             |                                   | 18.9 – deteriorated              |                                 |
| 2013c; Rowe et al. [21]        | Prospective       | Stroke survivors with suspected visual impairment | Variable over 2 weeks to 6 months | 915                               | 7.5 – full recovery 39.2 – partial recovery | Confrontation Static perimetry Kinetic perimetry |
|                                |                   |                  |                                             |                                   | 1 – deterioration 52.3 – static |                                 |
Table 8. Recovery of eye movement deficits

| Study                      | Design                  | Population                                | Time of vision assessment                  | Sample size (n=) | Prevalence of visual issue (%)                                                                 | Assessment          |
|---------------------------|-------------------------|-------------------------------------------|--------------------------------------------|------------------|-----------------------------------------------------------------------------------------------|---------------------|
| 1982; De Renzi et al. [62] | Prospective             | General stroke                            | Follow-up every 3-4 days for 2 weeks post onset | 91               | 8.6 days - mean duration to improvement with left stroke<br>14.9 – mean duration to improvement with right stroke | NIHSS               |
| 1987; Freeman & Rudge [35] | Prospective             | General stroke                            | Up to 12 months post onset                 | 76               | 7 – full improvement<br>50 – partial improvement<br>43 – stable<br>92 – improvement in stereoacuity within 1 month | Orthoptic           |
| 2011; Rowe et al. [18]    | Prospective             | Stroke survivors with suspected visual impairment | Variable over 2 weeks to 6 months         | 915              | Cranial nerve palsy: 22.5 – full improvement<br>43 – partial improvement<br>3.5 – deterioration<br>Nystagmus: 42 – partial improvement<br>24 – stable<br>Gaze palsy: 4 – full improvement<br>66 – partial improvement<br>30 - stable | Orthoptic           |
| 2013; Ali et al. [30]     | Prospective             | Stroke trial database                     | Baseline, 30 days and 90 days             | 11900 at baseline 4965 at follow-up | Complete gaze palsy: – at 30 days<br>Versus 14.5% at baseline<br>Partial gaze palsy: 9 – at 30 days<br>Versus 31% at baseline | NIHSS Confrontation |
### Table 9. Recovery of central vision deficit

| Study                        | Design                   | Population                                         | Time of vision assessment          | Sample size (n=) | Prevalence of visual issue (%) | Assessment   |
|------------------------------|--------------------------|----------------------------------------------------|------------------------------------|-----------------|-------------------------------|--------------|
| 1987; Freeman & Rudge [35]   | Prospective observation  | General stroke                                     | Median within 1 week of onset       | 247             | 71 – improvement               | Medical Orthoptic |
| 2011; Rowe et al. [19]       | Prospective              | Stroke survivors with suspected visual impairment  | Variable over 2 weeks to 6 months  | 915             | 10.5 – full improvement        | Orthoptic    |

### Table 10. Recovery of visual perceptual impairment

| Study                        | Design                   | Population                                         | Time of vision assessment          | Sample size (n=) | Prevalence of visual issue (%) | Assessment   |
|------------------------------|--------------------------|----------------------------------------------------|------------------------------------|-----------------|-------------------------------|--------------|
| 1987; Freeman & Rudge [35]   | Prospective              | General stroke                                     | Up to 4 months post onset          | 247             | Visual neglect: 29 – complete recovery 57 - stable | Medical Orthoptic |
| 1998; Cassidy et al. [79]    | Prospective              | General stroke with left hemisphere lesions excluded| Monthly follow-up                  | 66              | 9.1 – visual neglect at 3 months Versus 40.9% at baseline | Behavioural inattention test |
| 2004; Farne et al. [88]      | Prospective              | R hemisphere only                                  | Follow-up at 2 weeks and 3 months post onset | 33 at baseline 8 at 3 months | 43 – improvement at 2 weeks [9 – full] 63 – improvement at 3 months | Behavioural inattention test |
| 2007; Poggel et al. [89]     | Prospective              | Post-geniculate lesions                            | Mean 36 months (7-189 months), up to 6 months follow-up. | 19              | Visual hallucinations persisted for several days/weeks and then gradually subsided | Interview |
| 2007; Poggel et al. [89]     | Retrospective questionnaire | Mixed population                                   | Up to 6 months follow-up           | 121             | Mean duration of 28 days       | Questionnaire |
| 2013; Ali et al. [30]        | Prospective              | Stroke trial database                              | Baseline, 30 days and 90 days      | 11900 at baseline 4965 at follow-up | 0.6 – visual neglect at 90 days Versus 27.7% at baseline | NIHSS Confrontation |
Accuracy of non-specialist vision assessments and accuracy of screening tools and scores is likely to impact on reported prevalence figures. Where basic screening is undertaken, it is possible to miss subtle visual problems whose ocular signs are not included in the screening assessment. Thus there is the potential for underdiagnoses when the assessment is performed by the stroke team rather than an eye team specialist or where screening tools are used which only measure specific features of vision, e.g. detection of hemianopia or horizontal gaze defects only as with the NIHSS, or reliance on basic confrontation assessment rather than detailed confrontation or perimetry assessment.

Studies that report sub populations of stroke survivors are also prone to reporting bias for visual problems. Despite large sample sizes in studies that have included sub populations of stroke survivors, such as the VIS study of those already suspected of having visual impairment or studies of clinical trial databases, these studies are unlikely to be representative of the general stroke population. These estimates are potential under- or over-representations of the true prevalence of visual problems across all stroke survivors.

The time of the baseline assessment is crucial for studies tracking the recovery of visual impairment. If the baseline assessment is delayed, complete or partial recovery may have already taken place. Furthermore, it has not yet been accurately established at what time point recovery of each visual problem following stroke can be expected. If a study only has short period of follow-up, recovery could continue after the participant has completed the study. Both factors result in under-estimation of recovery of stroke-related visual impairment.

Future studies are required to establish the incidence for post-stroke visual impairment in the early acute period within the first week of onset. Such studies should involve a full stroke cohort with no exclusions so that visual impairment rates are comprehensively evaluated. These patients require follow-up at regular time intervals to plot change in visual impairment over the first week, first month and longer term after stroke onset to provide information on trajectory of improvement, if any, and rates for full, partial or no recovery. At baseline and follow-up visits, full specialist assessment is required such that subtle visual deficits that can cause visual impairment are not missed.

8. CONCLUSIONS

The literature currently available for review does not include any studies whose primary aim was to determine incidence or prevalence of visual impairment post stroke. Thus, this review can only provide estimates of prevalence for individual stroke related visual problems. The estimation of the overall prevalence of visual impairment was approximately 65% at baseline assessment. A reduction to approximately 20% is seen by three month post stroke, due to factors such as recovery, adaptation and death. The figures reported cover a wide range of prevalence for each visual problem. A variety of factors may be the cause of this wide range of figures including; the different study aims, research methods used, baseline assessments being conducted at different time points and different methods assessment. The prevalence is reported as being highest for eye movement defects, visual field loss and visual inattention. The existing literature regarding the recovery of visual problems following stroke is scarce for both individual deficits and overall visual recovery. Further prospective studies are required to establish the incidence of post-stroke visual impairment, the prevalence at various time periods post stroke and trajectory of improvement.

ETHICAL APPROVAL

It is not applicable.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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# APPENDIX

## Appendix 1 – PRISMA 2009 Checklist

| Title | 1 | Identify the report as a systematic review, meta-analysis, or both. | 1 |
|-------|---|------------------------------------------------------------------|---|
| **Abstract** | 2 | Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number. | 1 |
| **Introduction** | 3 | Describe the rationale for the review in the context of what is already known. | 2 |
| Rationale | 4 | Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS). | 2 |
| **Methods** | 5 | Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number. | N/A |
| Eligibility criteria | 6 | Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale. | 2-3 |
| Information sources | 7 | Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched. | Appendix 2 |
| Search | 8 | Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated. | Appendix 2 |
| Study selection | 9 | State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis). | 2-3 |
| Data collection process | 10 | Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators. | 4 |
| Data items | 11 | List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made. | 3-4 |
| Risk of bias in individual studies | 12 | Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis. | 4 |
| Appendix 5 | 13 | State the principal summary measures (e.g., risk ratio, difference in means). | N/A |
| Summary measures | 14 | Describe the methods of handling data and combining results of studies, if done, including measures of consistency | N/A |
| Synthesis of results | 15 | | |
| Risk of bias across studies | 15 Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies). |
|----------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| Additional analyses        | 16 Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified. |

| Results                     |
|-----------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| Study selection             | Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram. |
| Study characteristics       | For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations. |
| Risk of bias within studies | Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12). |
| Results of individual studies | For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot. |
| Synthesis of results        | Present results of each meta-analysis done, including confidence intervals and measures of consistency. |
| Risk of bias across studies | Present results of any assessment of risk of bias across studies (see Item 15). |
| Additional analysis         | Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]). |

| Discussion                  |
|-----------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| Summary of evidence         | Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers). |
| Limitations                 | Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias). |
| Conclusions                 | Provide a general interpretation of the results in the context of other evidence, and implications for future research. |

| Funding                     |
|-----------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| Funding                     | Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review. |

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. DOI: 10.1371/journal.pmed1000097. Available: www.prisma-statement.org
Appendix 2. Search Options and Search Terms

Databases:

- Cochrane Stroke Group Trials Register
- The Cochrane Eyes and Vision Group Trials Register
- The Cochrane Central Register of Controlled Trials (CENTRAL) (*The Cochrane Library*, latest issue);
- MEDLINE (1950 to April 2015);
- EMBASE (1980 to April 2015);
- CINAHL (1982 to April 2015);
- AMED (1985 to April 2015);
- PsycINFO (1967 April 2015);
- Dissertations & Theses (PQDT) database (1861 to April 2015);
- British Nursing Index (1985 to April 2015);
- PsycBITE (Psychological Database for Brain Impairment Treatment Efficacy, [www.psycbite.com](http://www.psycbite.com)).

Registers:

- ClinicalTrials.gov ([http://clinicaltrials.gov/](http://clinicaltrials.gov/));
- Current Controlled Trials ([www.controlledtrials.com](http://www.controlledtrials.com));
- Trials Central ([www.trialscentral.org](http://www.trialscentral.org));
- Health Service Research Projects in Progress ([wwwcf.nlm.nih.gov/hsr_project/home_proj.cfm](http://wwwcf.nlm.nih.gov/hsr_project/home_proj.cfm));
- National Eye Institute Clinical Studies Database ([http://clinicalstudies.info.nih.gov/cgi/protinstitute.cgi?NEI.0.html](http://clinicalstudies.info.nih.gov/cgi/protinstitute.cgi?NEI.0.html))
- 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](http://pcwww.liv.ac.uk/~rowef/index_files/Page646.htm))
- Proceedings of Association for Research in Vision and Ophthalmology ([www.arvo.org](http://www.arvo.org));

Terms:

| Cerebrovascular disorders/ | Eye Movements/ |
|---------------------------|----------------|
| Brain ischaemia/          | Eye/           |
| Intracranial Arterial Disease | Eye Disease/   |
| Intracranial Arteriovenous Malformations/ | Visually Impaired Persons/ |
| "Intracranial Embolism and Thrombosis"/ | Vision Disorders/ |
| Stroke/                   | Blindness/     |
|                           | Diplopia/      |
|                           | Vision, Binocular/ |
|                           | Vision, Monocular/ |
|                           | Visual Acuity/ |
|                           | Visual Fields/ |
|                           | Vision, Low/   |
| Ocular Motility Disorders/ | OR |
|---------------------------|----|
| 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              |    |
| ophthalmoplegia           |    |
| Parinaud's syndrome       |    |
| Weber's syndrome          |    |
| skew deviation            |    |
| conjugate deviation       |    |
| oscillopsia               |    |
| visual tracking           |    |
| agnosia                   |    |
| hallucinations            |    |

OR

AND
Appendix 3. Flowchart of Pathway for Inclusion of Articles

1. Titles identified through database searching, n = 109,281
   - Excluded n = 87,091
     - Duplicates
     - Case studies
     - Editorials
     - Letters
     - Not Relevant

2. Titles and abstracts screened, n = 22,190
   - Excluded n = 21,938
     - Not relevant to the review

3. Studies identified from searching reference lists, n = 31

4. Full-text articles retrieved and assessed for eligibility, n = 283
   - Articles related to visual problems following stroke, n = 131
     - Articles meeting inclusion criteria relating to prevalence and recovery, n = 64
     - Excluded n = 152
       - (Table 3)
       - Not relevant n = 32
       - Review article n = 30
       - General population n = 20
       - Case study or small case series n = 14
       - <50% stroke diagnosis n = 27
       - Other non-empirical articles n = 7
       - Visual defects not discussed n = 5
       - Abstract only n = 3
       - Insufficient information n = 7
       - Included in Cochrane Systematic review n = 5
       - Duplicate n = 2
### Appendix 4. Excluded Articles

| Study                        | Reason for exclusion                                                                 |
|------------------------------|--------------------------------------------------------------------------------------|
| Ajina and Kennard, 2012      | Review article                                                                       |
| Al-Khayat et al., 2005       | No stroke patients included                                                          |
| Anderson and Rizzo, 1994     | Case report                                                                          |
| Anderson and Rizzo, 1995     | Review article                                                                       |
| Baier et al., 2010           | Not relevant to the review – preselected cases                                        |
| Barker et al., 2012          | Not relevant to the review – assessment of neuropsychology                            |
| Barnes et al., 2006          | Unable to distinguish number of stroke patients                                       |
| Barrett, 2009                | Review article                                                                       |
| Bartolomei et al., 1998      | No stroke patients included                                                          |
| Beran and Murphy-Lavoie, 2009| Not related to stroke                                                                 |
| Beck and Harris, 1994        | Not related to stroke – general population                                           |
| Behrmann et al., 2004        | Not relevant to the review – addresses different types of search patterns in neglect |
| Biousse et al., 1998         | Only reported on three patients                                                       |
| Blythe et al., 1987          | Not relevant to the review – preselected cases assessed for blindsight               |
| Bodis-Wollner and Diamond, 1973| Unable to establish the proportion of participants were post-stroke, participants reported to have cerebral lesions. |
| Bodis-Wollner and Diamond, 1976| Unable to establish the proportion of participants were post-stroke, participants reported to have cerebral lesions. |
| Bombois et al., 2007         | Stroke patients excluded                                                             |
| Bronstein et al., 1990       | Unable to establish the proportion of participants were post-stroke                  |
| Brown Jr et al., 1998        | A general population sampled                                                         |
| Brunette, 1967               | Review article                                                                       |
| Bulsara et al., 2007         | No stroke patients included                                                          |
| Bunce and Wormald, 2008      | A general population sampled                                                         |
| Bunce et al., 2010           | A general population sampled                                                         |
| Büttner and Grunde, 1995     | Sample included 50% or fewer stroke patients                                         |
| Buxbaum et al., 2008         | Not relevant to the review – performance on wheelchair navigation                    |
| Caneman et al., 1992         | Not relevant to the review – performance on maze test                                 |
| Carlow and Bicknell, 1981    | Review article                                                                       |
| Carman-Merrifield, 2005      | Review article                                                                       |
| Cheek et al., 1965           | Sample included 50% or fewer stroke patients                                         |
| Cheung et al., 2008          | Not relevant to the review - discussed retinal pathology                             |
| Chia et al., 2004            | A general population sampled                                                         |
| Ciuffreda et al., 2006       | Sample included 50% or fewer stroke patients                                         |
| Ciuffreda et al., 2007       | Sample included 50% or fewer stroke patients                                         |
| Reference                          | Type                          |
|-----------------------------------|-------------------------------|
| Clenet, 2011                      | Case study                    |
| Cockburn, 1983                    | A general population sampled  |
| Colombo et al., 1981              | Not relevant to the review – preselected cases from a larger cohort |
| Cooper, 1971                      | Not relevant to stroke        |
| Cooper et al., 2012               | Only reported on two patients |
| Crews et al., 2006                 | Sample included 50% or fewer stroke patients |
| Danta et al., 1978                 | Sample included 50% or fewer stroke patients |
| Das et al., 2007                   | Review article                |
| Dennis et al., 1990               | Not relevant to the review – transient ischaemic attacks |
| Di Legge et al., 2004              | Correspondence to the editor  |
| Dulli et al., 1998                 | No reference to visual problems |
| François, 1975                     | Review article                |
| Fraser et al., 2011                | Review article                |
| Galanth et al., 2014               | Visual problems of stroke patients not discussed |
| Gállego et al., 2008               | Review article                |
| Gamio and Melek, 2003              | Case report                    |
| George et al., 2011                | Protocol article              |
| Georgiadis et al., 1999           | No reference to visual problems |
| Gilhotra et al., 2002              | A general population sampled  |
| Gilhotra et al., 2002              | A general population sampled  |
| Giroud et al., 1994                | Not relevant to review – focused on seizures after stroke |
| Globe et al., 2005                 | A general population sampled  |
| Goldstein and Simel, 2005          | Review article                |
| Good et al., 2001                  | Not relevant to review - paediatric population |
| Gottlieb and Miesner, 2004         | Review article                |
| Grunda et al., 2013                | Review article                |
| Guenther et al., 2009              | Not relevant to the review – evaluating prediction model |
| Habekost and Starrfelt, 2006       | Case report                    |
| Hankey, 1997                       | A general population sampled  |
| Hofman et al., 2007                | A general population sampled  and study protocol update |
| Hofman et al., 2011                | A general population sampled  and study protocol update |
| Horton, 2005                       | Editorial                      |
| Howard et al., 2006                | Unable to establish the proportion of participants were post-stroke |
| Jagger et al., 1989                | No stroke patients included   |
| Jarvis et al., 2012                | Not relevant to the review – information provided to the stroke team |
| Jensen et al., 2009                | Case study                    |
| Jin et al., 2010                   | No stroke patients included   |
| Jobke et al., 2009                 | Already included in a Cochrane Systematic Review |
| Authors                          | Type                  | Notes and Details                                                                 |
|---------------------------------|-----------------------|-----------------------------------------------------------------------------------|
| Jones and Shinton, 2006         | Review article        |  |
| Jungehülsing et al., 2008       | A general population sampled |  |
| Kasten et al., 2007             | Sample included 50% or fewer stroke patients |  |
| Kasten et al., 2006             | Sample included 50% or fewer stroke patients |  |
| Kerkhoff and Stögerer, 1994     | No stroke patients included |  |
| Kim and Kim, 2005               | Not relevant to the review – restricted to midbrain stroke only |  |
| Kissel et al., 1983             | No stroke patients included |  |
| Klavora and Warren, 1998        | Not relevant to the review - overview of equipment, no participant data presented |  |
| Książkiewicz and Sobczak-Kamińska, 1998 | Not relevant to the review - eye assessment related to level of consciousness |  |
| Kumar, 2006                     | News article          |  |
| Kuppersmith et al., 1996        | No stroke patients included |  |
| Lamoreux et al., 2008           | A general population sampled |  |
| Langelaan et al., 2007          | A general population sampled |  |
| Leff et al., 2000               | Sample included 50% or fewer stroke patients |  |
| Leff and Behrmann, 2008         | Review article        |  |
| Leśniak and Seniów, 2007        | Review article        |  |
| Lessell, 1975                   | Review article        |  |
| Levine, 2006                    | Letter to editor      |  |
| Lisabeth et al., 2009           | Unable to distinguish with numbers of stroke and TIA patients |  |
| Macfarlane and Jolly, 1995      | Not relevant to the review – role of the orthoptist |  |
| Markowitz, 2009                 | Review article        |  |
| Marshall et al., 2008           | Not relevant to the review - fMRI study |  |
| Marx et al., 1992               | A general population sampled |  |
| McKean et al., 2014             | Not relevant to the review – predicting factors on imaging of stroke |  |
| Mead et al., 2002               | Visual problems of stroke patients not discussed |  |
| Merten, 2001                    | Review article        |  |
| Mitchell et al., 1996           | A general population sampled |  |
| Nazerian et al., 2014           | Sample included 50% or fewer stroke patients |  |
| Nazzarko, 2007                  | Review article        |  |
| Neikter, 1999                   | Only conference abstract available |  |
| Nelles et al., 2009             | Not relevant to the review – training effects on neural plasticity |  |
| Niu et al., 2005                | Not relevant to the review – examines location of lesion for neglect |  |
| Olbert, 1985                    | Case study            |  |
| O'Neill et al., 2011            | Sample included 50% or fewer stroke patients |  |
| Pambakian et al., 2005          | Review article        |  |
| Patel et al., 2004              | Sample included 50% or fewer stroke patients |  |
| Patino et al., 2010             | A general population sampled |  |
| Pelak et al., 2007              | Review article        |  |
| Peli, 2000                      | Sample included 50% or fewer stroke patients |  |
| Reference                          | Details                                                                 |
|-----------------------------------|-------------------------------------------------------------------------|
| Petzold et al., 2013              | Not related to stroke patients                                         |
| Piechocki, 2004                   | News article                                                           |
| Poggel et al., 2004               | Already included in a Cochrane Systematic Review                       |
| Proto et al., 2009                | Review article                                                         |
| Purvin, 1996                      | Review article                                                         |
| Purvin, 2004                      | Review article                                                         |
| Racette and Casson, 2005          | Not relevant to the review – impact on driving                         |
| Rafalowska et al., 1972           | Only reported on three patients                                        |
| Ramrattan et al., 2001            | A general population sampled                                           |
| Riise, 1969                       | No stroke patients included                                            |
| Ritchie et al., 2012              | Only reported on two patients                                          |
| Ross, 1983                        | Not relevant to the review – selected sample                           |
| Rossi et al., 1990                | Already included in a Cochrane Systematic Review                       |
| Rowe, 2009                        | Duplicate – subset sample                                              |
| Rowe, 2010                        | Not relevant to the review                                             |
| Rutner et al., 2006               | Sample included 50% or fewer stroke patients                           |
| Sabel and Kasten, 2000            | Review article                                                         |
| Sabel and Mueller, 2005           | Only abstract available                                                 |
| Sabel and Trauzettel-Klosinski, 2005 | Expert debate                                                          |
| Sahraie et al., 2010              | Case study                                                             |
| Sand et al., 2013                 | Review article                                                         |
| Schofield and Leff, 2009          | Review article                                                         |
| Schwartz et al., 2012             | Not relevant to the review – assessment of eye position using CT scan  |
| Shiraishi et al., 2004            | Stroke patients not identified separately                              |
| Simon et al., 2003                | Not relevant to the review – assessment of eye position using CT scan  |
| Spitzyna et al., 2007             | Already included in a Cochrane Systematic Review                       |
| Suchoff et al., 2008              | Sample included 50% or fewer stroke patients                           |
| Tsai et al., 2003                 | Sample included 50% or fewer stroke patients                           |
| Unwin et al., 1999                | Only conference abstract available                                     |
| Vahlberg and Hellström, 2008      | Review article                                                         |
| van der Graaff et al., 2000       | Case study                                                             |
| Viken et al., 2014                | Not relevant to the review – predicting functional outcomes            |
| Weinberg et al., 1977             | Already included in a Cochrane Systematic Review                       |
| Williams et al., 2003             | Visual problems not discussed                                          |
| Wolter and Preder, 2006           | Review article                                                         |
| Woo and Mandelman, 1983           | Case report                                                            |
| Zhang et al., 2006                | Duplicate report of study already included in the review               |
| Zhou et al., 2013                 | A general population sampled                                           |
| Zihl, 1980                        | Only reported on three patients                                        |
| Zihl et al., 1988                 | Not relevant to the review                                             |
| Zihl and Hebel, 1997              | Sample included 50% or fewer stroke patients                           |
| Zihl et al., 2009                  | Not relevant to the review – selected sample                            |
Appendix 5. Quality Appraisal of Papers Using the STROBE Checklist

|                      | Introduction | Methods  | Results  | Discussion |
|----------------------|--------------|----------|----------|------------|
| Agrell et al., 1997 [45] | + | + | + | + | ? | - | + | + | + | + | + | - | + | - |
| Akhtar et al., 2009 [68] | + | + | + | + | - | ? | + | + | + | n/a | + | - | - | + |
| Ali et al., 2013 [30] | + | + | + | + | - | - | - | ? | ? | + | + | + | + | + |
| Appelros et al., 2002 [74] | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
| Baier and Dieterich, 2011 [67] | - | + | + | + | + | - | - | + | + | + | + | + | - | + |
| Barrett et al., 2007 [38] | + | + | + | - | - | - | + | - | + | + | + | + | + | + |
| Beaudoin et al., 2013 [82] | + | + | + | + | + | - | - | + | + | + | + | + | + | + |
| Becker and Karnath, 2007 [76] | + | + | + | + | - | + | - | + | + | + | + | n/a | + | + |
| Benedetti et al. 1993 [48] | + | + | + | - | + | - | - | + | + | + | + | + | + | + |
| Bulens et al 1989 [71] | - | - | + | + | + | - | - | + | + | + | + | + | + | + |
| Cassidy et al., 1998 [79] | + | + | + | + | - | - | + | - | + | n/a | + | + | + | - |
| Cassidy et al. 1999 [80] | + | + | + | + | - | - | + | - | + | n/a | + | - | + | - |
| Cassidy et al., 2001 [46] | + | + | + | + | + | + | - | + | + | + | + | + | + | + |
|                  | 3  | 4  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Celesia et al., 1997 [54] | +  | +  | +  | +  | +  | -  | +  | +  | -  | +  | +  | +  | +  | +  | +  | +  | +  | +  | -  |
| Chechlacz et al., 2014 [84] | -  | +  | -  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| Clisby, 1995 [32] | +  | -  | -  | -  | -  | -  | -  | -  | +  | -  | +  | -  | -  | -  | -  | -  | -  | -  | -  |
| De Renzi et al., 1982 [62] | -  | +  | +  | +  | +  | +  | +  | -  | +  | +  | +  | +  | +  | n/a | +  | -  | +  | +  | +  |
| Dos Santos et al., 2012 [72] | +  | -  | +  | +  | +  | +  | -  | +  | +  | +  | +  | +  | +  | n/a | +  | +  | +  | +  | +  |
| Edwards et al., 2006 [70] | +  | +  | +  | +  | +  | -  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| Farné et al., 2004 [89] | +  | +  | -  | +  | +  | -  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| Fowler et al., 1996 [58] | +  | +  | +  | +  | -  | +  | +  | -  | +  | +  | +  | +  | +  | n/a | +  | -  | +  | +  | +  |
| Freeman and Rudge, 1987 [35] | +  | +  | +  | +  | -  | +  | +  | -  | +  | +  | +  | +  | +  | n/a | +  | +  | +  | +  | +  |
| Gall et al., 2010 [31] | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | n/a | +  | +  | +  | +  | +  |
| Gray et al., 1989 [41] | +  | +  | +  | +  | +  | +  | +  | -  | +  | +  | +  | +  | +  | n/a | +  | +  | +  | +  | +  |
| Haerer, 1973 [47] | +  | +  | +  | +  | -  | -  | +  | -  | -  | +  | +  | +  | +  | n/a | +  | +  | +  | +  | +  |
| Isaeff et al., 1974 [33] | -  | +  | ?  | -  | -  | -  | -  | -  | +  | -  | +  | +  | +  | n/a | -  | -  | -  | -  | -  |
| Jerath et al., 2011 [53] | +  | +  | +  | +  | -  | +  | +  | -  | +  | +  | +  | +  | +  | n/a | +  | +  | +  | +  | +  |
| Kedar et al., 2007 [55] | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| Lawrence et al., 2001 [49] | +  | +  | +  | +  | -  | -  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
|                | 3 | 4 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|----------------|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|
| Lee et al., 2009 [78] | - | + | + | + | + | - | + | + | - | + | + | + | + | + | + | - | + | - |
| Linden et al., 2006 [75] | + | + | + | + | - | + | + | + | + | + | + | + | n/a | + | - | + | - |
| Lottery et al., 2000 [64] | + | + | + | + | - | - | + | - | - | + | + | + | n/a | + | - | - | - |
| Maeshima et al., 2012 [59] | - | + | + | + | - | + | + | + | + | + | + | + | + | n/a | + | - | - | - |
| Ng et al., 2005 [50] | + | + | + | + | + | + | + | + | + | + | + | + | - | - | - | - |
| Pedersen et al., 1997 [73] | + | + | + | + | - | + | + | + | + | + | + | + | + | - | - | - |
| Poggel et al., 2007 [89] | - | + | + | + | - | + | + | + | + | + | + | + | + | - | - | - |
| Rathore et al., 2002 [52] | - | - | + | + | - | - | + | + | + | + | + | + | + | + | - | - |
| Rowe, 2007 [69] | + | + | + | + | - | - | + | + | + | + | + | + | + | + | + | - |
| Rowe et al., 2008 [66] | + | + | + | + | - | - | + | + | + | + | + | + | + | - | - | + |
| Rowe et al., 2009 [24] | + | + | + | + | - | - | + | + | + | + | + | + | + | + | - | - |
| Rowe et al., 2009 [6] | + | + | + | + | - | - | + | + | + | + | + | + | + | + | + | - |
| Rowe et al., 2010 [23] | + | + | + | + | - | - | + | + | + | + | + | + | + | + | - | - |
| Rowe et al., 2011 [18] | + | + | + | + | - | - | + | + | + | + | + | + | + | + | + | - |
| Rowe et al., 2011 [19] | + | + | + | + | - | - | + | + | + | + | + | + | + | + | + | - |
| Rowe et al., 2013 [36] | + | + | + | + | - | - | + | + | + | + | + | + | + | + | + | - |
|                           | 3 | 4 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---------------------------|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|
| Rowe et al., 2013 [22]    | + | + | + | + | - | - | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| Rowe et al., 2013 [21]    | + | + | + | + | - | - | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| Schmielau and Wong Jr, 2007 [86] | + | - | + | + | + | - | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| Searls et al., 2012 [42]  | + | + | + | + | - | - | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| Shrestha et al., 2012 [81] | + | + | + | + | - | - | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| Siddique et al., 2009 [65] | - | + | + | - | - | - | +  | -  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| Singer et al., 2006 [63]  | - | + | + | + | - | - | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| Siong et al., 2014 [61]   | + | + | + | + | - | - | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| Stone et al., 1993 [56]   | + | + | + | + | - | - | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| Su and Young, 2013 [60]   | - | + | + | + | - | - | +  | -  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| Tao et al., 2012 [43]     | + | + | + | - | - | - | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| Tiel and Kömel, 1991 [85] | - | + | + | - | - | - | +  | -  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| Townsend et al., 2007 [51] | - | + | + | + | - | - | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| Trobe et al., 1973 [34]   | - | + | - | - | - | - | +  | -  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| van Nes et al., 2009 [77] | + | + | + | + | - | - | +  | -  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| Yang et al., 2014 [83]    | + | + | + | + | + | + | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
|                         | 3 | 4 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|-------------------------|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|
| Yap et al., 1975 [57]   |  +|  +|  +|  +|  −|  −|  +|  +|  +|  −|  +|  +|  +|  +| n/a|  +|  −|  −|  −|  −|
| Zhang et al., 2006a [44]|  +|  +|  +|  +|  +|  +|  −|  +|  +|  +|  +|  +|  +|  +| +  | -  | +  | +  | +  | +  |
| Zhang et al., 2006b [87]|  +|  +|  +|  +|  +|  +|  −|  +|  +|  +|  +|  +|  +|  +| n/a| +  | +  | +  | +  | +  |

- = Not reported;  ? = Unclear;  + = Reported

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