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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 lead 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 We searched scholarly online resources and hand searched journals and registers of published, unpublished and ongoing trials.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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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 paresis 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].

2.3 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 paper 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 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]. The studies described to date, frequently report when the stroke has affected the posterior circulation, including the cerebellum [42,60,67,68]. 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 observation	General stroke	Median within 3 months of onset	322	62	Yes	Medical
1987; Freeman & Rudge [35]	Prospective observation	General stroke	Median within 1 week of onset	247	63	Yes	Medical Orthoptic
1995; Clisby [32]	Prospective observation	General stroke	Acute period on stroke unit	140	71	Yes	Orthoptic
2007; Barrett et al. [38]	Prospective observation	General stroke	Unknown	505	19	Unknown	NIHSS and Questionnaire for verifying stroke-free status
2009; Rowe et al. [6]	Prospective observation	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	Unknown	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 observation	General stroke	Unknown	265	25 – homonymous hemianopia/ quadrantanopia	Unknown	Confrontation
1974; Isaeff et al. [33]	Prospective observation	General stroke	Median within 3 months of onset	322	17 – visual field loss	Ocular pathology	Confrontation
1989; Gray	Prospective observation	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]			and max to 28 days		46.6 – hemianopia 10.3 – quadrantanopia		
1993; Benedetti et al. [48]	Prospective observation	General stroke	Median within 48 hours of admission	94	19.1 – homonymous hemianopia	Unknown	Unknown
1995; Clisby [32]	Prospective observation	General stroke	Acute period on stroke unit	140	47 – visual field loss	Ocular pathology	Confrontation Campimetry
1997; Agrell et al. [45]	Prospective observation	General stroke	Median within 3 months of onset	67	30 – homonymous hemianopia	Visual inattention	Confrontation
1997; Celesia et al. [54]	Prospective observation	Stroke survivors with hemianopia	Median within 24 hours of onset	32	100 – homonymous hemianopia 62 – asymptomatic	Unknown	Kinetic perimetry
2000; Lotery et al. [64]	Prospective observation	General stroke	Median within 3 months of onset	77	19.5 – visual field loss ¾ hemianopia	Ocular pathology	Unknown
2001; Cassidy et al. [46]	Prospective observation	General stroke	Median within 3 months of onset	148	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	61	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	915	49.5 – visual field loss ⅔ 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	1174	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 28 – gaze palsy 11 – impaired VOR 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 7 - nystagmus	Unknown	NIHSS
1987; Freeman & Rudge [35]	Prospective observation	General stroke	Median within 1 week of onset	247	22 – ocular motility disorders 35 – strabismus (additional 6% pre-existent) 18 – palsies (skew deviation:3 1 ½ syndrome 6 Horizontal gaze palsy 57% Vertical gaze palsy 20%] 23 - nystagmus	Yes	Medical Orthoptic
1995; Clisby [32]	Prospective observation	General stroke	Acute period on stroke unit	140	52 – strabismus 44 – gaze palsy: 90 – horizontal with right hemisphere stroke 73 – horizontal with left hemisphere stroke 39 – cranial nerve palsy (mainly III) 55- reduced vergence and stereoacuity	Ocular pathology	Orthoptic
1996; Fowler et al. [58]	Prospective observation	Mixed neurological on	Median within 2 months of	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	Unknown	NIHSS
2007; Rowe et al. [70]	Prospective observation	Stroke survivors with suspected visual impairment	Median within 3 weeks of onset	243	54 – reduced convergence <6cms. 26 – 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 – nystagmus N=2 – pre-existent N=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	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
					palsy 22.2 – impaired gaze holding 3.9 – Parinaud's syndrome 9.7 – INO 1.4 – one and a half syndrome		
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 [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; Lotery 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 stereoacuity	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
					2.4 – visual neglect [left hemisphere] 4.9 – visual extinction		
2009; Lee et al. [78]	Prospective	General stroke Left hemisphere excluded	Median within 2 months of onset	138	58 – visual neglect 22.5 – neglect dyslexia	Unknown	Test battery
2009; van Nes et al. [77]	Prospective	General stroke Excluded aphasia, gaze palsy, cognitive issues	Median within 2 weeks of onset	78	21.8 – visual neglect 88 – right hemisphere	Gaze paresis excluded	Cancellation tasks
2009; Rowe et al. [6,24]	Prospective	Stroke survivors with suspected visual defect	Median within 3 weeks of onset	323	14 – visual neglect 4 – visual hallucinations 2.5 – visual agnosia	Yes	Test battery
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 4.6 right visual extinction	Unknown	Confrontation 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 (>3^{o}) 76 – ipsiversive 24 – contraversive 54.7 – abnormal torsion	Unknown	Computerised assessment

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]	Prospective	General stroke	Mean 73 day follow-up1 week to 6 months	247	33 – improvement (22 full, 11 partial) 25 – stable field	Confrontation
1989; Gray et al. [41]	Prospective	General stroke	Followed every 24 hours for 4 days and max to 28 days	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
al. [46]					11.1 - stable	
2013; Ali et al. [30]	Prospective	Stroke trial database	Baseline, 30 days and 90 days	11900 at baseline 4965 at follow-up	Complete hemianopia: 13 at 30 days 10 at 90 days Versus 35% at baseline Partial hemianopia: 11 at 90 days Versus 14.5% at baseline	NIHSS Confrontation
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 63 – stable field	Perimetry Central 30 or 24 degrees
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: 38.1 – improvement 58.5 – stable field 3.4 – deteriorated Incongruous hemianopia: 39.6 – improvement 41.5 – stable field 18.9 – deteriorated	Perimetry Central 30 or 24 degrees
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 1 – deterioration 52.3 – static	Confrontation Static perimetry Kinetic perimetry

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 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 50 – partial improvement 43 – stable 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 43 – partial improvement 3.5 – deterioration Nystagmus: 42 – partial improvement 24 – stable Gaze palsy: 4 – full improvement 66 – partial improvement 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 Versus 14.5% at baseline Partial gaze palsy: 9 – at 30 days 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 43.4 – partial improvement 44.7 – stable 1.3 - deteriorated	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 [6, 30]. 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.

REFERENCES

1. Pollock A, et al. Interventions for disorders of eye movement in patients with stroke. Cochrane Database of Systematic Reviews. 2011;10.

2. Pollock A, et al. Interventions for visual field defects in patients with stroke. Cochrane Database of Systematic Reviews. 2011;10.
3. Pollock A, et al. Interventions for age-related visual problems in patients with stroke. Cochrane Database of Systematic Reviews. 2012;3.
4. Bowen A et al. Cognitive rehabilitation for spatial neglect following stroke. Cochrane Database of Systematic Reviews. 2013;7.
5. Jones SA, Shinton RA. Improving outcome in stroke patients with visual problems. Age & Ageing. 2006;35(6):560-565.
6. Rowe F et al. Visual impairment following stroke: do stroke patients require vision assessment? Age & Ageing. 2009;38(2): 188-193.
7. Granger CV et al. Functional assessment scales: A study of persons after stroke. Archives of Physical Medicine & Rehabilitation. 1993;74(2):133-138.
8. Nelles G, et al. Compensatory visual field training for patients with hemianopia after stroke. Neuroscience Letters. 2001;306(3): 189-192.
9. Ramrattan RS, et al. Prevalence and causes of visual field loss in the elderly and associations with impairment in daily functioning: The rotterdam study. Archives of Ophthalmology. 2001;119(12): 1788-1794.
10. West CG, et al. Is vision function related to physical functional ability in older adults? Journal of the American Geriatrics Society. 2002;50(1):136-145.
11. Tsai SY, et al. Association between visual impairment and depression in the elderly. Journal of the Formosan Medical Association. 2003;102(2):86-90.
12. Maberley DAL, et al. The prevalence of low vision and blindness in Canada. Eye. 2006;20(3):341-346.
13. Hyman L, et al. Prevalence and causes of visual impairment in the Barbados eye study1. Ophthalmology. 2001;108(10): 1751-1756.
14. Hsu WM, et al. Prevalence and causes of visual impairment in an elderly Chinese population in Taiwan1: The shihpai eye study. Ophthalmology. 2004;111(1):62-69.
15. Rodriguez J, et al. Causes of blindness and visual impairment in a population-based sample of U.S. Hispanics. Ophthalmology. 2002;109(4):737-743.
16. Klein R, Klein BEK, Lee KE. Changes in visual acuity in a population. Ophthalmology. 1996;103(8):1169-1178.
17. Marmamula S, et al. A cross-sectional study of visual impairment in elderly population in residential care in the South Indian state of Andhra Pradesh: A cross-sectional study. BMJ Open. 2013;3(3).
18. Rowe F. Prevalence of ocular motor cranial nerve palsy and associations following stroke. Eye. 2011;25(7):881-887.
19. Rowe F, et al. Reading difficulty after stroke: Ocular and non ocular causes. International Journal of Stroke. 2011;6(5): 404-411.
20. Pollock A, et al. Interventions for visual field defects in patients with stroke. Stroke. 2012;43(4):e37-e38.
21. Rowe F et al. A prospective profile of visual field loss following stroke: Prevalence, type, rehabilitation and outcome. Bio Med Research International; 2013.
22. Rowe F, et al. Profile of gaze dysfunction following cerebro vascular accident. ISRN Ophthalmology; 2013.
23. Rowe F, et al. The profile of strabismus in stroke survivors. Eye. 2010;24(4):682-685.
24. Rowe F. Visual perceptual consequences of stroke. Strabismus. 2009;17(1):24-28.
25. University of York centre for reviews and dissemination. PROSPERO: International prospective register of systematic reviews. 2013;27:2015.
Available:http://www.crd.york.ac.uk/PROSPERO/
26. Von Elm E, et al. Strengthening the reporting of observational studies in epidemiology (STROBE): Guidelines for reporting observational studies. Plos Medicine. 2007;4(10):1623-1627.
27. Vandenbroucke JP, et al. Strengthening the reporting of observational studies in epidemiology (STROBE): Explanation and elaboration. Plos Medicine. 2007;4(10): 1628-1654.
28. Sanderson S, Tatt ID, Higgins JP. Tools for assessing quality and susceptibility to bias in observational studies in epidemiology: A systematic review and annotated bibliography. International Journal of Epidemiology. 2007;36(3):666-676.
29. Boyle MH, Guidelines for evaluating prevalence studies. Evidence-Based Mental Health. 1998;1(2):37-39.
30. Ali M, et al. Recovery from poststroke visual impairment: Evidence from a clinical

trials resource. Neurorehabilitation & Neural Repair. 2013;27(2):133-141.
31. Gall SL, et al. Sex differences in presentation, severity, and management of stroke in a population-based study. Neurology. 2010;74(12):975-981.
32. Clisby C. Visual assessment of patients with cerebrovascular accident on the elderly care wards. British Orthoptic Journal. 1995;52:38-41.
33. Isaeff WB, Wallar PH, Duncan G. Ophthalmic findings in 322 patients with a cerebral vascular accident. Annals of Ophthalmology. 1974;6(10):1059-1064.
34. Trobe JD, Lorber ML, Schlezinger NS. Isolated homonymous hemianopia. A review of 104 cases. Archives of Ophthalmology. 1973;89(5):377-381.
35. Freeman CF, Rudge NB. The orthoptist's role in the management of stroke patients. in 6th International Orthoptic Congress. Harrogate, UK; 1987.
36. Rowe F, et al. Symptoms of stroke-related visual impairment. Strabismus. 2013;21(2): 150-154.
37. Rothwell PM, External validity of randomised controlled trials: "To whom do the results of this trial apply?" The Lancet. 2005;365(9453):82-93.
38. Barrett KM, et al. Sex differences in stroke severity, symptoms, and deficits after first-ever ischemic stroke. Journal of Stroke & Cerebrovascular Diseases. 2007;16(1):34-39.
39. Lyden P, et al. Underlying structure of the national institutes of health stroke scale: Results of a factor analysis. Stroke. 1999; 30(11):2347-2354.
40. Jones WJ, Williams LS, Meschia JF, Validating the questionnaire for verifying stroke-Free status (Qvsfs) by neurological history and examination. Stroke. 2001; 32(10):2232-2236.
41. Gray CS, et al. Recovery of visual fields in acute stroke: Homonymous hemianopia associated with adverse prognosis. Age and Ageing. 1989;18(6):419-421.
42. Searls DE, et al. Symptoms and signs of posterior circulation ischemia in the new England medical center posterior circulation registry. Archives of Neurology. 2012;69(3):346-351.
43. Tao WD, et al. Posterior versus anterior circulation infarction: How different are the neurological deficits? Stroke. 2012;43(8): 2060-2065.
44. Zhang X, et al. Homonymous hemianopias: Clinical-anatomic correlations in 904 cases. Neurology. 2006;66(6): 906-910.
45. Agrell BM, Dehlin OI, Dahlgren CJ. Neglect in elderly stroke patients: A comparison of five tests. Psychiatry and Clinical Neurosciences. 1997;51(5):295-300.
46. Cassidy TP, Bruce DW, Gray CS, Visual field loss after stroke: Confrontation and perimetry in the assessment of recovery. Journal of Stroke and Cerebrovascular Diseases. 2001;10(3):113-117.
47. Haerer AF. Visual field defects and the prognosis of stroke patients. Stroke. 1973; 4(2):163-168.
48. Benedetti MD, et al. Short term prognosis of stroke in a clinical series of 94 patients. The Italian Journal of Neurological Sciences. 1993;14(2):121-127.
49. Lawrence ES, et al. Estimates of the prevalence of acute stroke impairments and disability in a multiethnic population. Stroke. 2001;32(6):1279-1284.
50. Ng YS, et al. Clinical characteristics and rehabilitation outcomes of patients with posterior cerebral artery stroke. Archives of Physical Medicine and Rehabilitation. 2005;86(11):2138-2143.
51. Townend BS, et al. Perimetric homonymous visual field loss post-stroke. Journal of Clinical Neuroscience.2007;14(8):754-756.
52. Rathore SS, et al. Characterization of incident stroke signs and symptoms: Findings from the atherosclerosis risk in communities study. Stroke. 2002;33(11): 2718-2721.
53. Jerath NU, et al. Gender differences in presenting signs and symptoms of acute ischemic stroke: A population-based study. Gender Medicine. 2011;8(5):312-319.
54. Celesia GG, Brigell MG, Vaphiades MS, Hemianopic anosognosia. Neurology. 1997;49(1):88-97.
55. Kedar S, et al. Congruency in homonymous hemianopia. American Journal of Ophthalmology. 2007;143(5):772-780.
56. Stone SP, Halligan PW, Greenwood RJ, The incidence of neglect phenomena and related disorders in patients with an acute right or left hemisphere stroke. Age & Ageing. 1993;22(1):46-52.
57. Yap MHL, Loong SC, Nei IP. Eye signs in strokes. Annals of the Academy of Medicine Singapore. 1975;4(2):133-137.

58. Fowler MS, et al. Squints and diplopia seen after brain damage. Journal of Neurology. 1996;243(1):86-90.
59. Maeshima S, et al. Functional outcome in patients with pontine infarction after acute rehabilitation. Neurological Sciences. 2012;33(4):759-764.
60. Su CH, Young YH, Clinical significance of pathological eye movements in diagnosing posterior fossa stroke. Acta Oto-Laryngologica. 2013;133(9):916-923.
61. Siong KH, et al. Prevalence of visual problems among stroke survivors in Hong Kong Chinese. Clinical and Experimental Optometry. 2014;97:433-441.
62. De Renzi E, et al. Conjugate gaze paresis in stroke patients with unilateral damage. An unexpected instance of hemispheric asymmetry. Archives of Neurology. 1982; 39(8):482-486.
63. Singer OC, et al. Conjugate eye deviation in acute stroke: Incidence, hemispheric asymmetry, and lesion pattern. Stroke. 2006;37(11):2726-2732.
64. Lotery AJ, et al. Correctable visual impairment in stroke rehabilitation patients. Age and Ageing. 2000;29(3):221-222.
65. Siddique MAN, et al. Clinical presentation and epidemiology of stroke - A study of 100 cases. Journal of Medicine. 2009; 10(2):86-89.
66. Rowe F, et al. The spectrum of nystagmus following cerebro-vascular accident. British and Irish Orthoptic Journal. 2008;5:22-25.
67. Baier B, Dieterich M. Incidence and anatomy of gaze-evoked nystagmus in patients with cerebellar lesions. Neurology. 2011;76(4):361-365.
68. Akhtar N, et al. Ischaemic posterior circulation stroke in State of Qatar. European Journal of Neurology. 2009; 16(9):1004-1009.
69. Rowe F, et al. Visual impairment in stroke survivors: A prospective multi-centre trial. in 31st European Strabismological Association. Mykonos, Greece; 2007.
70. Edwards DF, et al. Screening patients with stroke for rehabilitation needs: Validation of the post-stroke rehabilitation guidelines. Neurorehabilitation and Neural Repair. 2006;20(1):42-48.
71. Bulens C, et al. Spatial contrast sensitivity in unilateral cerebral ischaemic lesions involving the posterior visual pathway. Brain. 1989;112(Pt 2):507-520.
72. Dos Santos NA, Andrade SM. Visual contrast sensitivity in patients with impairment of functional independence after stroke. BMC Neurology. 2012;12:90.
73. Pedersen PM, et al. Hemi neglect in acute stroke--incidence and prognostic implications. The Copenhagen Stroke Study. American Journal of Physical Medicine & Rehabilitation. 1997;76(2):122-127.
74. Appelros P, et al. Neglect and anosognosia after first-ever stroke: Incidence and relationship to disability. Journal of Rehabilitation Medicine. 2002; 34(5):215-220.
75. Linden T, et al. Visual neglect and cognitive impairment in elderly patients late after stroke. Acta Neurologica Scandinavica. 2005;111(3):163-168.
76. Becker E, Karnath HO. Incidence of visual extinction after left versus right hemisphere stroke. Stroke. 2007;38(12):3172-3174.
77. Van Nes IJ, et al. Is visuospatial hemineglect really a determinant of postural control following stroke? An acute-phase study. Neurorehabilitation & Neural Repair. 2009;23(6):609-614.
78. Lee BH, et al. Neglect dyslexia: Frequency, association with other hemispatial neglects, and lesion localization. Neuropsychologia. 2009;47(3):704-710.
79. Cassidy TP, Lewis S, Gray CS. Recovery from visuospatial neglect in stroke patients. Journal of Neurology, Neurosurgery & Psychiatry. 1998;64(4): 555-557.
80. Cassidy TP, et al. The association of visual field deficits and visuo-spatial neglect in acute right-hemisphere stroke patients. Age & Ageing. 1999;28(3):257-260.
81. Shrestha GS, et al. Ocular-visual defect and visual neglect in stroke patients - A report from Kathmandu, Nepal. Journal of Optometry. 2012;5(1):43-49.
82. Beaudoin AJ, et al. Visuoperceptual deficits and participation in older adults after stroke. Australian Occupational Therapy Journal. 2013;60(4):260-266.
83. Yang TH, et al. Topology of brainstem lesions associated with subjective visual vertical tilt. Neurology. 2014;82:1968-1975.
84. Chechlacz M, et al. The frequency and severity of extinction after stroke affecting different vascular territories. Neuropsychologia. 2014;54:11-17.

85. Tiel K, Kolmel HW. Patterns of recovery from homonymous hemianopia subsequent to infarction in the distribution of the posterior cerebral artery. Neuro-Ophthalmology. 1991;11(1):33-39.
86. Schmielau FEK, Wong Jr. Recovery of visual fields in brain-lesioned patients by reaction perimetry treatment. Journal of Neuro Engineering and Rehabilitation. 2007;4.
87. Zhang X, et al. Natural history of homonymous hemianopia. Neurology. 2006;66: 901-905.
88. Farne A, et al. Patterns of spontaneous recovery of neglect and associated disorders in acute right brain-damaged patients. Journal of Neurology, Neurosurgery & Psychiatry. 2004;75(10):1401-1410.
89. Poggel DA, et al. Visual hallucinations during spontaneous and training-induced visual field recovery. Neuropsychologia. 2007;45(11):2598-2607.

APPENDIX

Appendix 1 – PRISMA 2009 Checklist

Title			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
Abstract			
Structured summary	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			
Rationale	3	Describe the rationale for the review in the context of what is already known.	2
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	2
Methods			
Protocol and registration	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
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	N/A
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency	N/A

		(e.g., I^2) for each meta-analysis.	
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).	4
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	N/A
Results			
Study selection	17	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.	4, Appendix 3
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Tables 1 to 10
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	4 Appendix 5
Results of individual studies	20	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.	Tables 1 to 10
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	N/A
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	4
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	N/A
Discussion			
Summary of evidence	24	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).	5-24
Limitations	25	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).	24-25
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	25
Funding			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	25

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).

Registers:

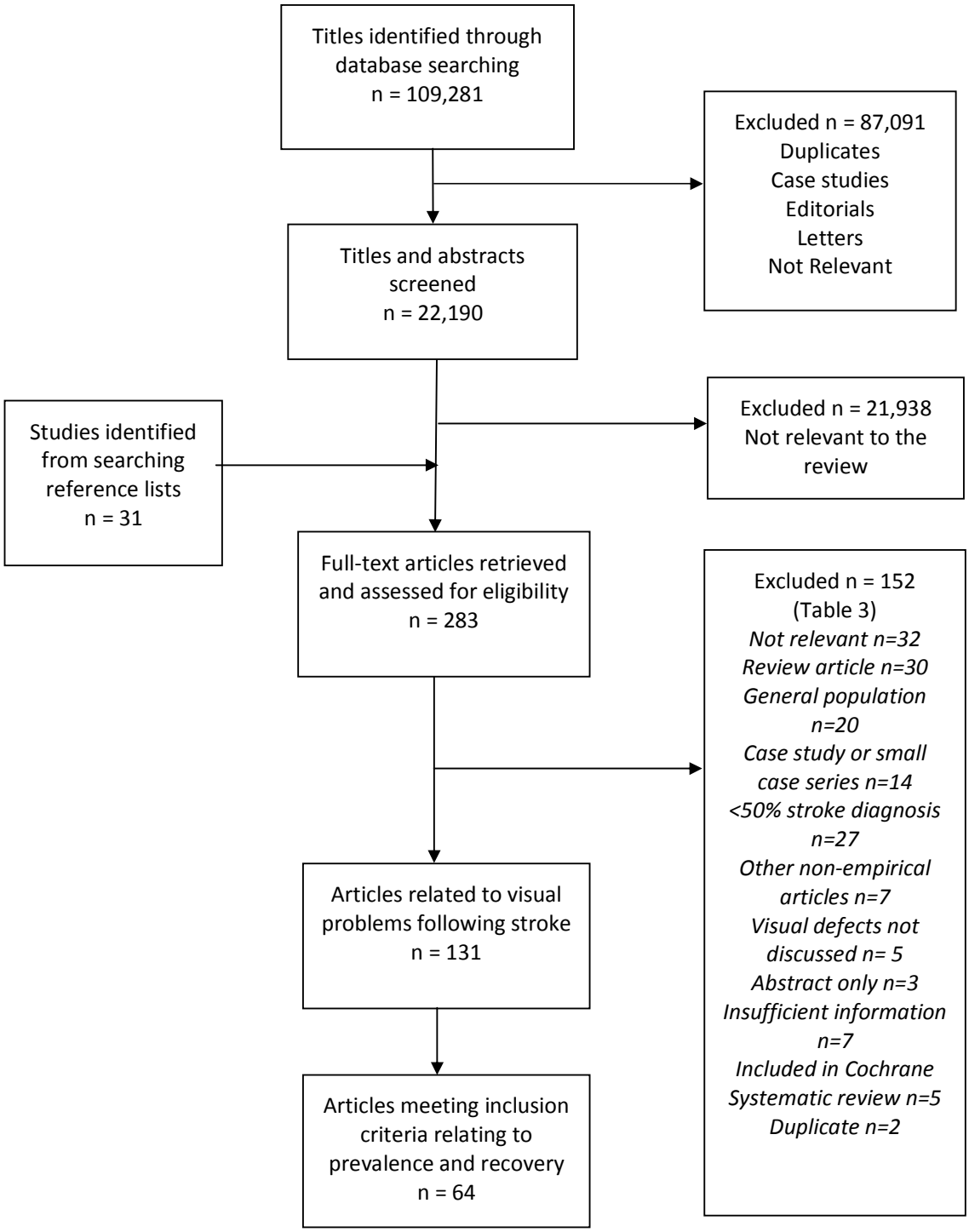
- ClinicalTrials.gov (http://clinicaltrials.gov/);
- Current Controlled Trials (www.controlledtrials. com);
- Trials Central (www.trialscentral.org);
- Health Service Research Projects in Progress (wwwcf.nlm.nih.gov/hsr_project/home_proj.cfm);
- National Eye Institute Clinical Studies Database (http://clinicalstudies.info.nih.gov/cgi/protinstitute.cgi?NEI.0.html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

Terms:

Cerebrovascular disorders/ Brain ischaemia/ Intracranial Arterial Disease Intracranial Arteriovenous Malformations/ “Intracranial Embolism and Thrombosis*/ Stroke/	Eye Movements/ Eye/ Eye Disease/ Visually Impaired Persons/ Vision Disorders/ Blindness/ Diplopia/ Vision, Binocular/ Vision, Monocular/ Visual Acuity/ Visual Fields/ Vision, Low/

	Ocular Motility Disorders/ Blindness, Cortical/ Hemianopsia/ Abducens Nerve Diseases/ Abducens Nerve/ Oculomotor Nerve/ Trochlear Nerve/ Visual Perception/ Nystagmus strabismus smooth pursuits saccades depth perception stereopsis gaze disorder internuclear opthalmoplegia Parinaud's syndrome Weber's syndrome skew deviation conjugate deviation oscillopsia visual tracking agnosia hallucinations
OR	OR
AND	

Appendix 3. Flowchart of Pathway for Inclusion of Articles



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 at 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 Grundei, 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

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

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

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
Rafałowska et al., 1972	Only reported on three patients
Ramrattan et al., 2001	A general population sampled
Riise, 1969	No stroke patients included
Ritchie at 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 Trauzettal-Klosinksi, 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			
	3	4	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
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]	-	+	+	+	+	-	-	-	-	+	+	+	+	n/a	+	-	+	+
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	+	-	+	-
Lotery 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 Kölmel, 1991 [85]	-	+	+	+	-	-	+	+	-	+	+	+	-	n/a	+	-	-	-
Townsend et al., 2007 [51]	-	+	+	+	+	+	+	+	+	+	+	+	+	n/a	+	-	-	+
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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