Impact of Visual impairment following Stroke (IVIS study): a prospective clinical profile of central and peripheral visual deficits, eye movement abnormalities and visual perceptual deficits.

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Abstract

Aim: This study evaluates the spectrum of visual impairment in stroke survivors.

Methods: The Impact of Visual Impairment after Stroke (IVIS) study is a multi-centre, acute stroke unit, prospective epidemiology study. Comprehensive visual examination was offered to all stroke survivors.

Results: 1500 stroke admissions were recruited. 1204 stroke survivors had visual assessment. Reduced central vision was documented in 529, visual field loss in 308, ocular motility abnormalities in 533 stroke survivors, visual perception deficits in 59 stroke survivors and visual inattention in 315 stroke survivors. About half, regardless of visual impairment type, were visually asymptomatic. Recovery, whether full or partial, was best for central vision, ocular motility abnormalities and visual perception deficits (about 70% improvement) occurring over a mean follow-up period of 2-3 months.

Conclusions: Incidence of impaired central vision, visual field loss, ocular motility disorders and visual inattention was 29.4%, 24.8%, 39.3% and 26.2% respectively. Visual impairment was more likely to occur in more severe stroke and older stroke survivors. Asymptomatic cases raises concerns for acute stroke units where robust specialist vision screening is not routine. Those with partial/no recovery require specialist follow-up and management whilst the wide range of abnormalities highlight the need for specialist visual assessment acutely.

Keywords: Stroke, Visual impairment, Incidence, Symptoms, Recovery

Introduction

Impaired vision following stroke is well recognised and reported, including eye movement abnormalities, visual perceptual deficits, reduced central vision and peripheral visual field loss [1]. Whilst visual inattention and visual field loss are most widely recognised as visual consequences of stroke, reduced central vision is more common but is recognised less [1-3]. We have reported point prevalence of central and peripheral vision loss previously as 56% and 28% respectively [2]. Ocular alignment and motility abnormalities also occur frequently with a reported prevalence of up to 68% [4]. Less is reported about disorders of visual perception (other than visual inattention). These are usually described in case reports or small case series but there are few collective reports of visual perception disorders in stroke survivor cohort studies [5].

With such visual impairments the impact to life after stroke for stroke survivors can be considerable. Stroke survivors with visual impairment have a poorer quality of life with impact to self-care and daily life activities [6,7]. Stroke-related visual impairment affects physical and social functioning in addition to emotional well-being [7,8].

The profile of visual impairment following stroke has received little attention. Monocular or binocular vision loss can be an isolated presentation of stroke [9]. Reduced central vision has largely been attributed to spectacle need or eye disease but with less consideration to new onset low vision after stroke [3,10]. Homonymous hemianopia is the most common form of visual field loss due to stroke but less is reported on other types of visual field loss [11,12]. Strabismus is an ocular misalignment in which both eyes no longer coordinate as a pair and usually causes the symptoms of blurred/jumbled or double vision (diplopia). The misaligned eye may

turn inwards, outwards, up, down or a combination [13]. Ocular motility abnormalities are varied following stroke and include ocular cranial nerve palsies, horizontal and vertical gaze palsies, nystagmus and deficits in saccadic, smooth pursuit and vergence eye movements. Resultant symptoms are often diplopia, oscillopsia, reading difficulty and altered vision [14].

Disorders of visual perception occur frequently following stroke with the most commonly recognised disorder being visual inattention/neglect [1,15]. Visual perception disorders can include impaired recognition (visual agnosia) of objects (object agnosia), faces (prosopagnosia) and colour (achromatopsia), impaired depth, impaired constancy (e.g. micropsia, macropsia), sight impairment recognition (e.g. Anton's syndrome, Riddoch phenomenon), and impaired motion or spatial detection (e.g. akinetopsia, polyopia, visual perseveration, palinopsia) [1, 15,16]. A further disorder, particularly following sight impairment, is visual hallucinations which may be formed or unformed and including Charles Bonnet syndrome [15,17].

In this study we aim to profile visual impairment following stroke in a large epidemiology study, taking into account the extent and type of visual impairment, associated symptoms and ocular deficits, management options and outcomes.

Methods

Population

The Impact of Visual Impairment after Stroke (IVIS) study was undertaken in three hospital hyper-acute and acute stroke units in the North West of England. The target

population was stroke survivors in the acute phase (within 2 weeks post stroke onset) following admission to hospital with a clinical diagnosis of stroke confirmed by the admitting stroke physician. Brain imaging data was collected, where available on hospital admission, from reports provided by the radiology team.

Ethical approval was obtained from the Health Regulatory Authority (Research Ethics Committee reference 14/NW/0166) and the study was undertaken in accordance with the Tenets of Helsinki. This paper was written in accordance with the STROBE statement [18].

Exclusion criteria were stroke survivors less than 18 years old. Inclusion criteria were stroke survivors 18 years of age or older with the ability to agree to vision screening using verbal or non-verbal indications of agreement.

Assessment

Assessment of visual function included:

- visual acuity for near and distance, monocular and binocular (logMAR, Cardiff grating acuity cards, Vocational near visual acuity, fixing and following observations),
- visual field assessment (visual fields to confrontation, static/kinetic perimetry),
- ocular alignment assessment (cover/uncover test),
- rotation of eye movements (saccadic and smooth pursuit movements),
- vergence (near point of convergence, divergence ability),
- simultaneous perception (Bagolini glasses),
- stereopsis (Frisby stereotest),
- fusional vergence (20 prism dioptre base-out, prism fusion range),
- lid and pupil function,

- visual perception (non-validated checklist; Figure 1 [19]),
- stereopsis (Frisby stereotest),
- visual inattention (line bisection, cancellation task, clock drawing, memory-guided tasks, room description, clinical observation).

Visual acuity was measured with appropriate spectacle correction, using logMAR charts with measurements in numerical increments up to 1.0 logMAR. Lower visual acuity measurements were graded as logMAR estimates of 1.5 for 3/60 acuity, 2.0 for hand movements/following face acuity, 2.5 for light perception and 5.0 for no perception of light.

Assessments on the stroke unit were initially carried out at the patient's bedside using portable equipment. Additional vision assessments were conducted where indicated to aid diagnosis. We sought verification of ocular history within the year prior to stroke onset. Where new onset impaired central vision was noted, checks for refractive error and ophthalmic pathology were made as part of the full specialist vision assessments to enable accurate diagnosis. We accounted for cases where reduced central vision could be attributed to the need for glasses update, new prescription, or to ocular conditions such as cataract, age-related macular degeneration, glaucoma or other eye disease plus for childhood onset conditions such as amblyopia and strabismus. A standardised assessment strategy was used with follow-up provided for those with visual impairment, usually at weekly intervals while an in-patient and, for out-patient visits, at 4, 12 and 26 weeks, and with allowance for longer follow-up where relevant according to individual patient needs [2].

Data were collected on stroke type, gender, age at stroke, ethnicity and stroke severity. Stroke severity was indicated by the Barthel score. This was chosen instead of the NIH stroke scale as the Barthel assessment is a measure of general functional performance based on activities of daily living and hence, was more relevant to our evaluation of impact of visual impairment among stroke survivors.

Low visual acuity was defined as worse than 0.5 logMAR (6/18 Snellen equivalent) by World Health Organisation levels [20] and also 0.3 logMAR (6/12 Snellen equivalent) by UK (Driver Vehicle Licencing Authority: DVLA) driving requirements [21]. Visual field loss was defined as loss of part of the central and/or peripheral field of vision, and classified by type, e.g. homonymous hemianopia, quadrantanopia, scotoma. Full recovery was defined as resolution of visual acuity to better than 0.2 logMAR (6/9 Snellen equivalent) and visual field boundaries for central and peripheral visual field equivalent to age-matched perimetry norms.

In the context of ocular motility abnormalities, binocular vision was defined as the strength and quality of the binocular co-ordination of the eyes in maintaining straight ocular alignment and inclusive of fusional vergence and stereopsis. Full recovery was defined as resolution of symptoms of visual perceptual deficit, pen/paper task responses within normal range, and objective clinical (by the multi-disciplinary stroke team) assessment of functional resolution for visual inattention.

Analysis

Descriptive statistics were used to report types of visual impairment and categories such as hemianopia, quadrantanopia, scotoma, gaze palsy, ocular cranial nerve palsy and strabismus, alexia, visual hallucinations and agnosia. Results of visual

function assessments were captured as numerical data. Independent samples analysis with chi square and Kruskal-Wallis tests were used for evaluation of stroke onset, gender, type of stroke and age. An independent t-test was used for parametric comparisons between groups and Mann Whitney test for non-parametric comparisons between groups.

Results

IVIS cohort

1500 stroke admissions were recruited over 15 months (1st July 2014 - 30th September 2015). Mean age at time of stroke was 73.27 years (SD 13.67) with 48.1% female and 51.9% male. Brain imaging was obtained by CT scan in 1289 (85.9%) stroke survivors and by MRI for 144 (9.6%). Sixty-seven (4.5%) did not have imaging reports available. Stroke type was infarction in 87.5% and haemorrhage in 12.5%, right-sided in 46.3%, left-sided in 47.9% and bilateral stroke in 5.5%. Stroke severity measured by Barthel score was a mean of 9.75 (SD 7.76). Ethnicity included white British (94.2%), white Irish (0.9%), other white (1.5%), Indian (0.6%), Pakistani (0.5%) and Chinese (0.5%).

296 did not have vision assessments; 116 died and 180 were unable to undergo assessment (figure 2). Of 1204 stroke survivors, 337 had normal eye examinations and were discharged from further vision follow-up. Of 867 found to have vision problems during assessment, 164 were attributed to prior ocular history including spectacle wear, childhood strabismus/amblyopia, and eye disease (e.g. glaucoma, age-related macular degeneration, diabetic retinopathy, cataract). New onset stroke-related visual problems were present in 703 stroke survivors. Visual assessments

were undertaken as soon as possible after admission to the acute stroke unit, using a standardised assessment strategy, and typically within the first week for the majority of stroke survivors as reported previously [2].

Stroke survivors who underwent vision assessment were younger (p=0.0001) and had less severe strokes (p=0.0001). Those not assessed (figure 2) or who died prior to vision assessment were more likely to be female (p=0.0001) and have haemorrhagic stroke (p=0.0001). Stroke survivors with new onset visual impairment were older in age (p=0.0001) and with more severe strokes (p=0.0001) than those with prior unrelated, or no, visual impairment. There was no significant difference for gender (p=0.365) or stroke type (p=0.083) (table 1). Thrombolysis was administered for 144 stroke survivors (4.9%). There was no significant difference for those having thrombolysis or not, with regard to presence of visual impairment or normal visual function (p=0.778).

Central visual impairment

Of 703 stroke survivors with visual impairment, 529 (75.2%) had impaired central vision (43.9% of assessed stroke survivors – point prevalence). Central visual impairment was due to prior causes and unrelated to the stroke in 175 stroke survivors and a new visual impairment in 354 stroke survivors (incidence of 29.4%). Mean age for this group was 76.4 years (SD 12.2) and mean Barthel score was 7.81 (SD 6.95). There were 46.7% females and 53.5% males, 89% infarct and 11% haemorrhage strokes. Area of brain involvement is outlined in figure 3a.

Of 354 stroke survivors with impaired central vision, 207 (58.5%) were visually asymptomatic. Visual symptoms were reported by 147 stroke survivors, primarily blurred/altered vision and reading difficulty (figure 4). Those that were asymptomatic

were more likely to be older (although not significantly, p=0.064) but had more severe stroke (p=0.0001).

Mean and median visual acuity levels for right and left eyes and binocular acuity are shown in table 2 for near and distance. Mean visual acuity levels of each eye were below low vision levels of 0.5 logMAR at first assessment (at mean 9.91 days, SD 25.85 days; median 4 days (0-369) post stroke onset). 81.4% (n=288) wore spectacles for their visual acuity assessment. Previous ocular history other than spectacles included attendance at eye clinics for unknown eye conditions (8.2%), childhood strabismus/amblyopia (5.4%) and known eye conditions (21.5%): glaucoma, cataract, macular degeneration, diabetic retinopathy, prosthesis. There were no reported past eye problems for 47.2% and past ocular history was unknown for 17.8%.

For those for whom driving status was known (n=179), 56 had given up driving prior to their stroke, six were driving and 45 had paused driving for the 4-week recommended period immediately following stroke. Seventy-two had never driven.

Reduced central vision was the sole visual impairment for 46 stroke survivors. For the remainder there were additional visual impairments including visual field loss (47.7%, n=169), visual inattention (49.7%, n=176), visual perceptual difficulty (8.5%, n=30) and ocular motility abnormality (74.9%, n=265).

Visual acuity improved on follow-up with a mean follow-up of 93.75 days (SD 102.84) after stroke; median 58 days (range 1-530). Full recovery (better than 0.2 logMAR) was recorded for 35.6% (n=126), partial recovery for 36.4% (n=129) and no recovery noted for 25.4% (n=90). The remaining stroke survivors did not have follow-up data because of illness, discharge or death. The time duration to attain full recovery was

47.71 days (SD 55.87; median 31 days (6-308)). Older stroke survivors were less likely to show recovery (p=0.029) but there was no significant difference for those with or without recovery in visual acuity levels for gender (p=0.266) or stroke severity (p=0.393).

A variety of management strategies were provided and typically targeted at the primary visual symptom. Most commonly, stroke survivors were referred to optometry or low vision services (51.7%) and given compensatory strategies and information resources (25.4%).

Visual fields

Of 703 stroke survivors with visual impairment, 308 (43.8%) had visual field loss (25.6% of assessed stroke survivors – point prevalence). Ten stroke survivors had visual field loss due to prior events (nine with constricted visual fields, arcuate defects or scotoma defects (glaucoma) and one with partial hemianopia due to a previous stroke). Of 298 stroke survivors with new onset visual field loss (incidence of 24.8%), 294 were entirely new onset and four stroke survivors had new visual field loss in addition to previous visual field loss: three had previous hemianopia but with new visual field loss on the other side and one had previous quadrantanopia with new extension.

Mean age for this group was 74.1 years (SD 12.9) and mean Barthel score was 7.4 (SD 7.33). There were 46.6% females and 53.4% males, 85.9% infarct and 14.1% haemorrhage strokes. Visual field loss was right sided in 47% (n=140), left sided in 48% (n=143) and bilateral in 5% (n=15). Area of brain involvement is outlined in figure 3b.

Stroke survivors reported no visual symptoms in 46% (n=137) despite presence of significant visual field loss such as hemianopia. The remaining stroke survivors reported mainly visual field loss (18.5%), blurred or altered vision (18.5%) amongst other symptoms (e.g. visual hallucinations, colour defect, depth impairment, dry eyes, photophobia, etc.; figure 4). Those that were asymptomatic were older (p=0.006) and had more severe stroke (p=0.0001). There was no significant difference for reporting symptoms regarding gender (p=0.471), stroke type (p=0.218), or if visual field loss was complete or partial (p=0.110).

For those for whom driving status was known (n=158), 54 had given up driving prior to their stroke, two were driving, three had given up driving following stroke as medically advised and 47 had paused driving for the 4-week recommended period immediately following stroke. Fifty-two had never driven. Type of visual field loss is shown in table 3. The most common type was homonymous hemianopia (72.5%).

Visual field loss was the sole visual impairment for 46 (15.4%) stroke survivors. For the remainder there were additional visual impairments including reduced central vision (77.5%, n=231), visual inattention (63.1%, n=188), visual perceptual difficulty (14.1%, n=42) and ocular motility abnormality (73.5%, n=219).

Visual field loss improved on follow-up with a mean follow-up of 70.19 days (SD 83.25) post stroke; median 38.5 days (range 8-426). Full recovery (normal visual field isopters) was recorded for 29.5% (n=88), partial recovery for 7.4% (n=22) and no recovery noted for 21.5% (n=64). The remaining stroke survivors did not have follow-up data because of illness, discharge or death. The time duration to attain full recovery was 52.36 days (SD 16.17; median 5 days (0-305)). Stroke survivors who recovered were not significantly different those with no recovery in terms of age

(p=0.267), gender (p=0.210) and stroke type (p=0.116). However, a significant difference was found for complete versus partial visual field loss (p=0.0001) in that recovery was more likely for partial hemianopia.

A variety of management strategies were provided and targeted at the primary visual symptom. These included scanning training (5.7%), reading strategies and training (11.1%), Peli prisms (2.0%) and other treatments for binocular vision symptoms (22.5%), low vision aids and prisms for diplopia.

Ocular motility abnormalities

Of 703 stroke survivors with visual impairment, 533 (75.8%) had ocular motility abnormalities (44.3% of assessed stroke survivors – point prevalence). Ocular motility abnormalities were due to prior causes and unrelated to the stroke in 60 stroke survivors. A prior history of childhood strabismus and/or amblyopia was present for 19 stroke survivors with further history of ocular disease for 26 stroke survivors. New ocular motility abnormalities were documented in 473 stroke survivors (39.3% of assessed stroke survivors – incidence); 448 stroke survivors had entirely new ocular motility abnormalities. Twenty-five stroke survivors had new ocular motility abnormalities but also had prior issues including; 21 with previous ocular motility abnormalities, two with previous ocular motility abnormalities and reduced central vision, one with previous strabismus and one with previous strabismus, ocular motility abnormality and reduced binocular vision.

Mean age for stroke survivors with ocular motility abnormalities was 74.22 years (SD 13.79) and mean Barthel score was 8.08 (SD 7.28). There were 45% female and 55% male, 90.5% infarct and 9.5% haemorrhagic strokes. The stroke lesion was

right-sided for 46.9%, left-sided for 46.7% and bilateral for the remainder. Area of brain involvement is outlined in figure 3c.

Of 473 stroke survivors with ocular motility abnormalities, 243 (51.4% were visually asymptomatic. Visual symptoms were reported by 230 stroke survivors, primarily blurred/altered vision, diplopia and reading difficulty (figure 4). Those that were asymptomatic were older (p=0.002), had more severe stroke (p=0.001) and were female (p=0.026). Although many reported visual symptoms on admission, others did not become aware or did not report visual symptoms until after the acute phase. The mean duration from stroke admission to reporting of visual symptoms was 16.02 days (SD 39.06; median 3 days, range 0-396). In comparison mean duration from stroke admission to time of diagnosis of ocular motility abnormality was 10.64 days (SD 21.21).

For those for whom driving status was known (n=256), 96 (37.5%) were drivers of which 91 had paused driving in keeping with recommendations for no driving within 4 weeks of stroke onset. Eighty-five had never driven, and 75 had given up in the years prior to their stroke.

Ocular motility abnormalities were the sole visual impairment for 87 (18.4%) stroke survivors. For the remainder there were additional visual impairments including reduced central vision (74.6%, n=353), visual inattention (44.2%, n=209), visual perceptual difficulty (8%, n=38) and visual field loss (41.9%, n=198).

Type of strabismus is shown in figure 5a for near and distance fixation. There was no ocular misalignment (i.e. co-ordinated straight eyes present in primary gaze) in 72.3% (n=342). Seventy (4.8%) of stroke survivors had strabismus at all distances, 25 (5.3%) had strabismus only at near distance, and eight (1.7%) had strabismus

only at far distance. Binocular vision deficits were present in 184 (38.9%) of stroke survivors consisting of reduced motor fusional vergence and/or impaired depth perception.

Type of ocular movement disorder is shown in figure 5b. Disorders of ocular movement were present in 384 (81.2%) of stroke survivors. The most common disorders were impaired elevation, horizontal gaze palsy, smooth pursuit palsy, saccadic dysmetria, impaired convergence and nystagmus. Of those with impaired convergence, this was absent for most (55 of 87 cases). Type of nystagmus is shown in figure 5c with the most common type being gaze evoked nystagmus.

Ocular motility abnormalities improved fully or partially, overall, for 328 (69.4%) of stroke survivors on follow-up with a mean follow-up of 97.43 days (SD 102.21) post stroke; median 58 days (range 1-529). Full recovery (straight ocular alignment with full ocular rotations and restored binocular vision) was recorded for 15% (ocular misalignment), 35.7% (ocular movement disorders) and 26% (binocular vision impairment). The time duration to attain full recovery was 88.58 days (SD 94.25) for ocular misalignment, 59.66 days (SD 64.71) for ocular movement disorders and 58.02 days (SD 66.58) for binocular vision impairment. Stroke survivors who recovered were not significantly different to those with no recovery in terms of stroke type ($p=0.365$). However, a significant difference was found for recovery versus no recovery for age ($p=0.002$; younger age for those showing recovery), gender ($p=0.031$; more females in non-recovered group), and stroke severity ($p=0.038$; less severe stroke for those showing recovery).

A variety of management strategies were provided and targeted at the primary visual symptom. These included prisms or occlusion (10.4%), scanning training (5.9%),

orthoptic exercises (1.3%), advisory and compensatory strategies (24.1%) and referral to optometry, low vision and ophthalmology clinics (50.7%).

Visual perception abnormality

Of 703 stroke survivors with visual impairment, 315 (44.8%) had new onset visual inattention (26.2% of assessed stroke survivors – incidence) and 59 (8.4%) had visual perceptual deficits other than visual inattention (4.9% of assessed stroke survivors – point prevalence).

Mean age for stroke survivors with visual inattention was 75.82 years (SD 6.01) and mean Barthel score was 12.63 (SD 6.35). There were 48.9% female and 51.1% male, 87.3% infarct and 12.7% haemorrhage strokes, 50.2% right-sided stroke, 47.0% left-sided stroke and 2.9% bilateral. Area of brain involvement is outlined in figure 3d.

Visual inattention was diagnosed through clinical observations by the multi-disciplinary stroke team in 174 (55.2%) stroke survivors and by pen and paper tasks in 141 (44.8%). Cases were recorded as mild in 95 (30.2%) and severe in 155 (49.2%) with the remaining stroke survivors not having the severity of visual inattention recorded. Visual inattention was left-sided in 123 stroke survivors (39.0%) and right-sided in 190 (60.3%). Side of inattention was not specified for two stroke survivors who had bilateral stroke and inconsistent responses on assessment and observation. There was no difference between mild or severe cases for age ($p=0.514$), stroke type ($p=0.334$) or right versus left side visual inattention ($p=0.510$). However those with severe visual inattention had worse stroke severity ($p=0.012$) and were more likely to be female ($p=0.006$).

Of 315 stroke survivors with visual inattention, visual symptoms were not reported by 184 (58.4%) stroke survivors. Visual symptoms were reported by 131 stroke survivors, primarily relating to other associated visual impairments such as blurred/altered vision, visual field loss and diplopia (figure 4) and at a mean of 17.1 days post stroke onset (SD 45.4). Additional visual impairments included reduced central vision (79.0%, n=249), visual perceptual deficits (8.6%, n=27), visual field loss (61.6%, n=194) and ocular motility abnormality (74.6%, n=235).

Only two stroke survivors reported visual symptoms relating to mild visual inattention. Those that were asymptomatic had more severe stroke (p=0.002); mean Barthel score of 5.0 (SD 5.9) for asymptomatic stroke survivors versus 7.4 (SD 6.7) for symptomatic stroke survivors. There was no significant difference for reporting symptoms regarding age (p=0.162), gender (p=0.185), stroke type (p=0.728) or stroke laterality (p=0.110).

For those for whom driving status was known (n=159), two were driving and 57 had paused driving on the recommendation of not driving within 4 weeks of stroke onset. Sixty had never driven and 40 had been previous drivers but had given up prior to their stroke. Prior/current driving status was unknown for 156 (49.5%) of stroke survivors.

Visual inattention improved on follow-up with a mean follow-up of 99.09 days (SD 102.17) post stroke. Full recovery was recorded for 45.1% (n=142), partial recovery for 15.2% (n=48) and no recovery noted for 38.1% (n=12017). Five remaining stroke survivors did not have follow-up data because of illness, discharge or death. The time duration to attain full recovery was 54.42 days (SD 56.22). Stroke survivors who recovered were not significantly different those with no recovery in terms of age

(p=0.190) and stroke type (p=0.518). However, a significant difference was found for stroke severity (p=0.05 – more severe strokes showed least recovery), gender (p=0.0001 – less females made a full recovery), severity of inattention (p=0.0001 – more severe inattention showed least recovery) and right versus left inattention (p=0.045 – more cases of right-sided inattention showed full recovery). However the time taken to achieve recovery was not significantly different for right versus left visual inattention or for mild versus severe cases.

A variety of management strategies were provided and targeted at the primary visual symptom. These included ophthalmology/optometry referral (44.1%), information resources (30.5%), scanning training (14.3%), low vision aids (4.1%) and options such as Peli prisms, prisms/patching for diplopia and reading strategies.

Visual perceptual deficit was due to prior causes and unrelated to the stroke in two stroke survivors; one stroke survivor with formed visual hallucinations due to age-related macular degeneration, and one stroke survivor with unformed visual hallucinations due to retinal disease. New deficits were recorded in 57 stroke survivors (4.7% of assessed stroke survivors – incidence). Mean age for this group was 71.02 years (SD 11.89) and mean Barthel score was 9.96 (SD 8.11). There were 49.1% female and 50.9% male, 94.7% infarct and 5.3% haemorrhage strokes. Area of brain involvement is outlined in figure 3d.

Of 57 stroke survivors with visual perceptual deficits, ten (17.5%) were visually asymptomatic. Visual symptoms were reported by 47 stroke survivors, primarily blurred/altered vision, visual field loss and visual hallucinations (figure 4d) and at a mean of 21.0 days post stroke onset (SD 37.3). Visual symptoms were not always reported at first assessment. One third reported visual symptoms at subsequent

follow-up eye assessments. Those that were asymptomatic had more severe stroke (p=0.0001); mean Barthel of 5.3 (SD 7.6) for asymptomatic stroke survivors versus 13.37 (SD 6.76) for symptomatic stroke survivors. There was no significant difference for reporting symptoms regarding age (p=0.169), gender (p=0.701), or stroke type (p=0.413).

For those for whom driving status was known (n=30), one was driving and six had paused driving on the recommendation of not driving within 4 weeks of stroke onset. Nine had never driven and 13 had been previous drivers but had given up prior to their stroke. Type of visual perceptual deficit is shown in figure 6. Twenty-two stroke survivors had a single visual perceptual deficit whilst 35 had multiple visual perceptual deficits. The most common overall type was visual hallucinations (82.5%). Additional visual impairments included reduced central vision (73.7%, n=42), visual inattention (47.4%, n=27), visual field loss (71.9%, n=41) and ocular motility abnormality (68.4%, n=39).

Visual perceptual deficits improved for 70.2% on follow-up with a mean follow-up of 175.89 days (SD 139.50) post stroke. Full recovery was recorded for 59.6% (n=34), partial recovery for 7.0% (n=4) and no recovery noted for 29.8% (n=17). Two remaining stroke survivors did not have follow-up data because of illness or discharge. The mean time duration to attain full recovery was 45.4 days (SD 34.95). Stroke survivors who recovered were not significantly different those with no recovery in terms of age (p=0.064), stroke severity (p=0.836), gender (p=0.312) and stroke type (p=0.946). However, a significant difference was found for type of visual perceptual deficit (p=0.037) in that recovery was twice as likely for visual hallucinations.

A variety of management strategies were provided and targeted at the primary visual symptom. These included optometry referral (38.6%), information resources (26.4%), scanning training (19.4%), reading strategies (7.1%), Peli prisms (1.8%) low vision aids (1.8%) and patching for diplopia (3.5%).

Discussion

In this study we report presence of central visual impairment, visual field loss, ocular motility abnormalities, visual inattention and visual perception deficits in 43.9%, 25.6%, 44.3%, 26.2% and 4.9% respectively of stroke survivors (point prevalence) and new onset (incidence) in 29.4%, 24.7%, 39.3%, 26.2% and 4.7% respectively of stroke survivors as a result of their stroke.

Prevalence of visual impairment in terms of central vision and visual field loss has been reported in the literature as up to 70% and 57% respectively [4,12,22,23]. We confirm previous reports that ocular motility abnormalities occur more frequently than the more commonly recognised visual impairments of homonymous hemianopia and visual neglect following stroke [1,24] with incidence of visual inattention similar to previously reported figures [5,25-27].

In addition to the timing of assessment, considerable variances in reporting of prevalence relates to the assessment method and choice of cohort (e.g. epidemiology study, right hemisphere stroke study, inclusion of suspected visual impairment only). The IVIS study differs here in that its design was as a prospective epidemiology study recruiting all stroke admissions over a defined time period and

with no exclusion criteria other than non-strokes and children. Thus, we report incidence in addition to prevalence rates for the cohort.

There were a proportion of our recruited cohort that could not be visually assessed at any time point; some because they died or because of other factors such as being medically unwell, on the end of life pathway, unable to attend an eye appointment or being discharged out of area. Significantly, those not assessed were older and had more severe strokes than those who underwent visual assessment. Arguably, if assessment had been possible, they may have been more likely to have visual impairment because of factors such as the greater severity of their stroke [10]. Stroke survivors who were confirmed as having visual impairment were also significantly older and with more severe strokes than stroke survivors who had no visual impairment or with pre-existent visual problems unrelated to their stroke.

Visual acuity is a primary measure of central visual function. The majority (81.4%) of stroke survivors needed glasses and wore their current glasses for visual acuity assessments. The mean near and distance visual acuities were below cut-off levels of low vision defined by the World Health Authority [20] and, by default, below levels acceptable for driving according to international driving regulations [21,28]. Our findings are similar to other studies reporting reduced central vision with reports of 15-25% at logMAR levels worse than 0.5 [29,30]. New onset reduced central vision may be due to stroke-related impact to the visual pathway. Arterial blood supply to the retina is from the central retinal artery – a branch from the anterior cerebral artery. Healthy vascular perfusion of the retina, and particularly the foveal and macular areas, is essential to high level central vision [2]. It is feasible that reduced central vision following stroke may reflect reduced perfusion and relative ischaemia

within the anterior visual pathway. Visual field loss was predominantly homonymous hemianopia and quadrantanopia as is frequently reported [31-34].

The types of strabismus and ocular motility disorders documented in this study were consistent with those reported in the literature with the most common form of strabismus being exotropia and the most common forms of ocular motility disorders being saccadic dysmetria and gaze palsies [1,10]. Often, strabismus in neurological conditions is due to coexistent ocular motility disorders, for example esotropia due to sixth nerve palsy or exotropia due to internuclear ophthalmoplegia. Isolated strabismus in neurological conditions is often a skew deviation [35,36]. However, a more common isolated neurological strabismus in stroke is exotropia which we confirm as prevalent in this study as in previous studies [5,37] and with the expected, but unusual, high number of asymptomatic cases in this particular form of exotropia.

The ocular motility disorders documented in this study were representative of those reported previously [1,24,38]. Vertical gaze palsies were more common than horizontal gaze palsies but it is recognised that gaze palsies, in general, are often caused by stroke [39] with site of stroke typically in the brainstem but often as very small lesions that can be easily missed on neuroimaging [40,41]. Convergence deficits were also common.

The most common type of visual perception disorder, after visual inattention, was visual hallucinations. These comprised both formed and unformed hallucinations. Formed visual hallucinations included those classed as complex (Charles Bonnet syndrome) [17,42]. Other visual perception disorders included achromatopsia, object agnosia, alexia, prosopagnosia, amongst many others, and similar to cases described in the literature [15,16,43-50]. Many visual perceptual disorders were

associated with other stroke-related visual impairments such as visual field loss; a recognised occurrence [5,48,51].

Driving is an important consideration for people with acquired visual impairment. Reduced central vision, double vision and visual field loss have a negative impact on the skills and level of sight needed for driving [52]. There were reduced numbers of stroke survivors with visual impairment who were known current drivers although known driving status could only be ascertained for about half of stroke survivors. Regulations for driving are strictly outlined internationally [21,28] but it was surprising that so few of our cohort were current drivers. About one-third had never driven and more had given up in recent years with older age and co-morbidities being potential factors explaining the latter. However, we acknowledge that it was not possible to obtain driving status information for half of those in this study so these figures could underestimate those actually driving up to the time of their stroke.

A high proportion of our stroke survivors were visually asymptomatic; 58.5% with reduced central vision, 46.0% with visual field loss, 51.4% with ocular motility abnormalities, 58.4% with visual inattention, but just 17.5% with visual perception deficits. These individuals were more likely to be older and had more severe strokes. Previous studies have reported visually asymptomatic rates of 55-62% [1,53]. Often the visual symptoms that stroke survivors report did not always point definitively to their primary underlying visual problem. For example, those with visual field loss quite often would state that their vision was ‘not quite right’ or ‘altered from before’ rather than describing a defined missing part of their field of vision. Those with visual inattention reporting visual symptoms were those relating to other coexistent visual impairments including blurred vision, visual field loss and diplopia. Symptom reporting in visual inattention is not usually expected unless there is awareness of

parts of the deficit [10,54,55]. Two of our patients reported visual symptoms specific to their visual inattention – notably both were mild cases. Significantly, our asymptomatic patients with either visual perception disorders or visual inattention were also those with more severe strokes. The lack of symptoms is linked to impaired activities of daily living, outcome and disability after stroke [23].

The symptom of diplopia was not as common as the symptom of blurred, altered or jumbled vision. Dadia and colleagues [24] reported diplopia as a symptom in just 12% of their cohort of stroke survivors, similar to this study. Walter and colleagues [35] noted that when strabismus angle is small, patients more often complain of blurred vision rather than diplopia, an observation which we agree with, based on our findings.

For visually asymptomatic stroke survivors, there is potential for these individuals to go undetected with regard to their visual impairment on the basis that no symptoms may indicate no impairment [23,32]. It is often only when more mobile and after discharge that these individuals begin to struggle because of their impaired vision [56-58]. This has a negative impact on stroke rehabilitation and functional independence [41,59,60]. This was particularly the case for stroke survivors with ocular motility disorders. Late reporting of visual symptoms also occurred for those with visual perception deficits, at an average of three weeks post-stroke onset. This highlights the difficulty in determining the presence of visual perception disorders by patient reporting alone. Indeed, it is known that patients with visual perceptual symptoms are less likely to report these symptoms for fear of stigma/mental decline that might be attributed to such unusual symptoms [5,16,61]. These factors contribute to the known under-reporting of visual perception disorders [42]. Unless members of the acute stroke team formally screen for visual function disorders

robustly, these deficits will go undetected. There is importance to these figures: whilst awareness of hemianopia and visual neglect remain high for clinicians who care for stroke survivors, awareness of ocular motility abnormalities, central visual impairment and visual perceptual deficits (other than inattention) is less with minimum targeted screening to enable detection of these visual problems.

In the absence of Orthoptic services, use of specific stroke/vision screening tools is advised [19,62]. Access to early and targeted management options for visual impairment can be further facilitated by integrated stroke/vision services [63,64].

Management options were targeted at primary visual symptoms including appropriate optometric assistance, low vision aids and compensatory strategies for impaired central vision, and visual scanning training and reading strategies for visual field loss.

A range of management strategies were targeted to the individual's visual symptoms such as visual scanning training, optometric assistance, low vision aids and reading strategies for impaired central vision and visual field loss, and patching or prisms to alleviate jumbled or double vision. Because of the very heterogenous profile of visual perception disorders management strategies can be difficult to apply but, for this cohort, were aimed at the individual visual symptoms. Our management strategies mirrored those reported previously and common in routine clinical eye care practice [1,63]. Further, we provided advice and compensatory strategies which are generally regarded as of being of benefit [1,2,65]. Ensuring prompt referral to specialist eye

services is essential to accessing the appropriate short- and long-term management for these visual impairments.

The outcomes for stroke survivors with visual impairment were promising. Overall, over half showed full or partial recovery. A high rate of recovery (over two thirds) was recorded for those with ocular motility abnormalities, impaired central vision and visual perception disorders and for 60% of those with visual inattention. Nearly 60% of those with visual perceptual deficits recovered fully within about 45 days from stroke onset, whilst just under 30% had no recovery. Recovery was particularly high for those with visual hallucinations. For visual inattention, 45% recovered fully within 2-3 months of stroke onset as assessed by pen and paper tasks although it is acknowledge that such tests may not fully reflect the extent of visual inattention for which some aspects are task dependent and with recovery over a longer time period [66].

Visual acuity levels showed improvement over an average follow-up period of 48 days (median 31 days) and over one-third recovered normal visual acuity, one-third had partial recovery and one quarter showed no improvement in their visual acuity. Recovery of reduced central vision is expected for many stroke survivors [23]. However, knowledge of a person's reduced vision in the first 48 days may help other members of the stroke team to optimise other rehabilitation therapies. Full recovery was recorded for 29.5% which occurred within a mean of 52.36 days (median 5 days). Partial recovery was noted for 7.4%. Our recovery rates are similar to the ranges reported in the literature and confirm a more rapid recovery trajectory for full recovery than those achieving partial recovery [10,23]. There was a higher number of stroke survivors with visual field loss that could not be followed up (e.g. subsequent death, discharge out of area). Thus, our recovery rates could be

underestimates. Full spontaneous recovery of hemianopia is reported to occur within 2-3 weeks of stroke onset with slower partial recovery occurring between 3-6 months following stroke [4,20,24-26]. We found partial hemianopia to have better recovery rates than complete hemianopia which confirms previous reports [21,22].

Recovery for ocular motility abnormalities was over an average period of up to three months which reflects recovery periods for neurological strabismus [13,26]. Full recovery ranged from 15-36% dependent on whether this was for strabismus, binocular vision and/or ocular motility disorder but with least full recovery for those with strabismus. Full recovery rates were less for our stroke survivors in comparison to ocular motility abnormalities from general neurological cohort studies. For example, recovery of isolated skew deviation is reported in 42% and recovery in ocular cranial nerve palsies due to microvascular causes in up to 85% of cases [13,27,28]. Thus, the aetiology and mechanism of cause of ocular motility abnormality is important when considering likely recovery.

In this study, those showing recovery were younger in age, more likely to be male and had less severe strokes. Conversely, lack of recovery was significantly associated with stroke severity and was worse for females. Notably there remains a persistent issue for those with partial or no recovery as they will have long-term needs for managing their visual symptoms and requiring specialist eye care for this. A small proportion of our stroke admissions received thrombolysis (<5%). Arguably, with better prevention and better access to acute interventions, outcomes would be substantially improved for stroke survivors.

Limitations

The IVIS study population was from the North West of England so caution must be exerted when considering generalisability of our findings to other geographic areas. Follow-up was not possible for all stroke survivors in this study. Further, for those receiving follow-up, this was constrained by study duration and therefore limited to 12 months post-stroke for the majority of stroke survivors. Thus, it is possible that the full extent of management options, such as long-term extraocular muscle surgery, were not captured for some cases. However, this was a pragmatic study reflecting typical clinical practice across three acute stroke units. All vision assessments were conducted by orthoptists. In the absence of orthoptists in acute stroke units and in other countries, use of robust, validated vision screening tools are recommended.

Conclusions

This prospective epidemiology study outlines the profile and outcomes of stroke survivors with visual impairment. Standardised visual assessments, in accordance with national clinical guidelines, underpinned this study and highlights the merits of appropriate vision services on acute stroke units. Visual impairment is common following stroke. We report incidence of 29.4%, 24.8% 39.3% and 26.2% respectively for impaired central vision, visual field loss, ocular motility abnormalities and visual inattention. Older age and stroke severity were significant for the presence of visual impairment. It is important that visual acuity, ocular motility and visual perception testing be incorporated as part of stroke screening as these are typically not formally assessed. About half of this cohort were visually asymptomatic which raises concerns for missed detection. Recovery was documented for over half of stroke survivors but with many requiring long-term management for partial or no

recovery that likely contribute to longer term unmet need for the individuals. This highlights the need for appropriate and timely referrals to ophthalmic and orthoptic services for specialist care. Persistent visual symptoms can impede general rehabilitation. Thus, early management for visual impairment is essential for general recovery and well-being.

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Figure 1, Visual perception checklist

Vision Impairment Screening Assessment (VISA)

Visual Symptoms **Section 1: History**

Ask the patient and their family/carers about the following.

History of eye care

- Does the person need glasses for near and/or distance vision?
- Are these broken or lost?
- Does the person have any previous eye history other than glasses? e.g. attending eye clinic for glaucoma, cataract, diabetes, macular degeneration, problems as a child, etc.
- When was their last eye check?

Symptoms

Is the person aware of?:

- Eye strain
- Reading – difficulty with reading because of their vision
- Blurred, altered or reduced vision
- Field loss – missing part of their peripheral vision
- Their full environment – inattention to one side
- Oscillopsia – wobbling images
- Diplopia – double or seeing two images
- Polyopia – seeing more than two images
- Visual hallucinations – seeing things that are not actually there, e.g. people, animals, lights, etc.
- Changes in seeing colours – colours washed out or black/white/grey
- Changes in seeing things move correctly, e.g. moving objects jump or there are repeated after images of the object
- Changes in depth, misjudging distances, pouring liquids
- Visual tilt – objects tilted on their side or upside down
- Visual illusions – objects that are distorted, larger or smaller than they should be
- Unable to recognise faces of familiar people
- Unable to pick out items/people in cluttered backgrounds
- Unable to recognise or name objects
- Getting lost
- Prolonged colour after-images
- Reverse size of images
- Falsely seeing static objects as moving
- Increased glare from surfaces
- Visual crowding
- Visual disorientation

Figure 2, Reasons for non-assessment

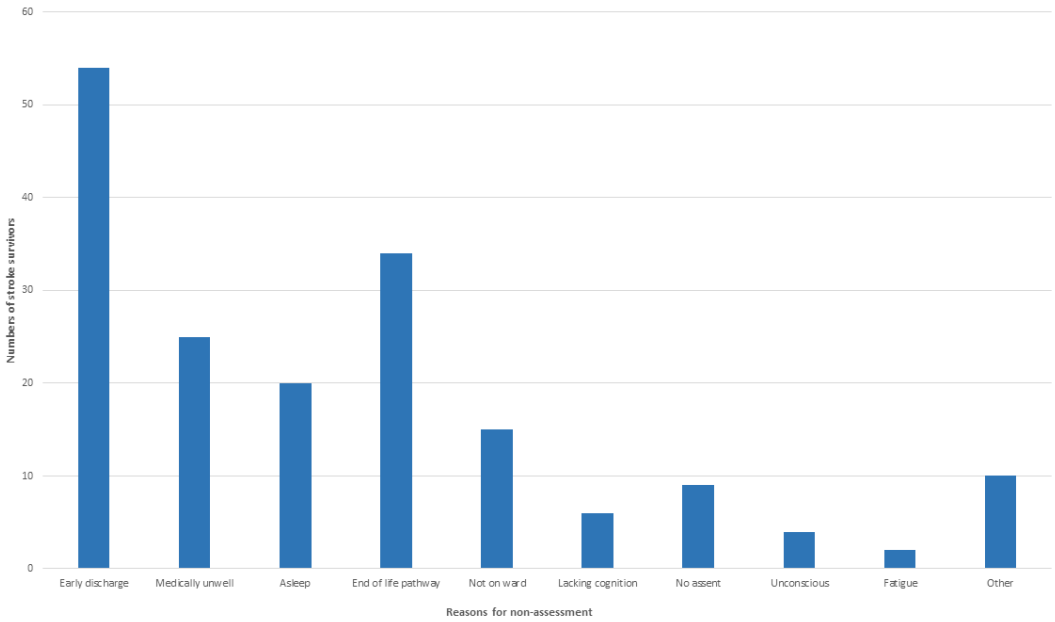
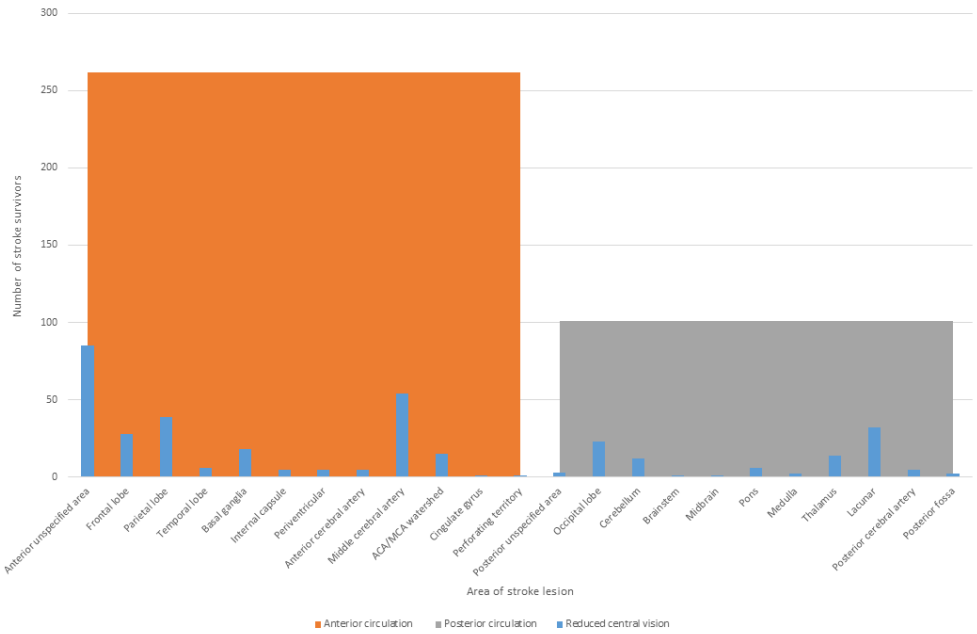
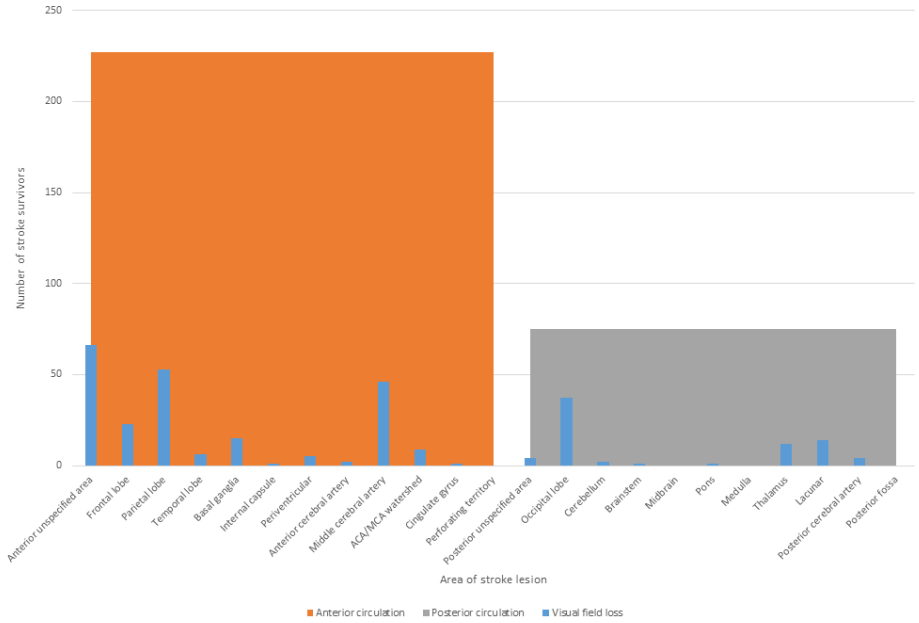


Figure 3, Area of primary stroke lesion in brain

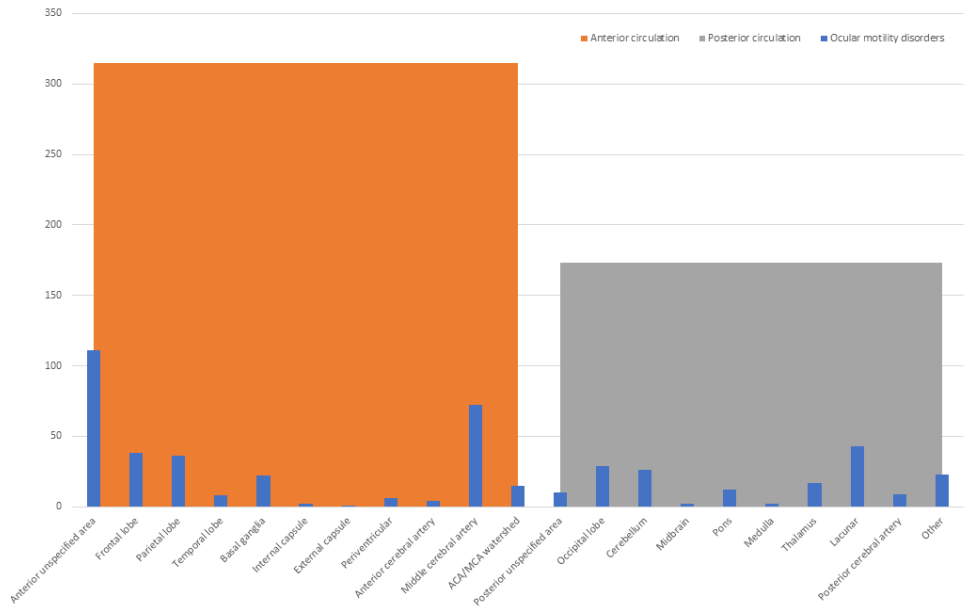
A, Central visual impairment



B, Visual field loss



C, Ocular motility disorders



D, Visual perception abnormalities

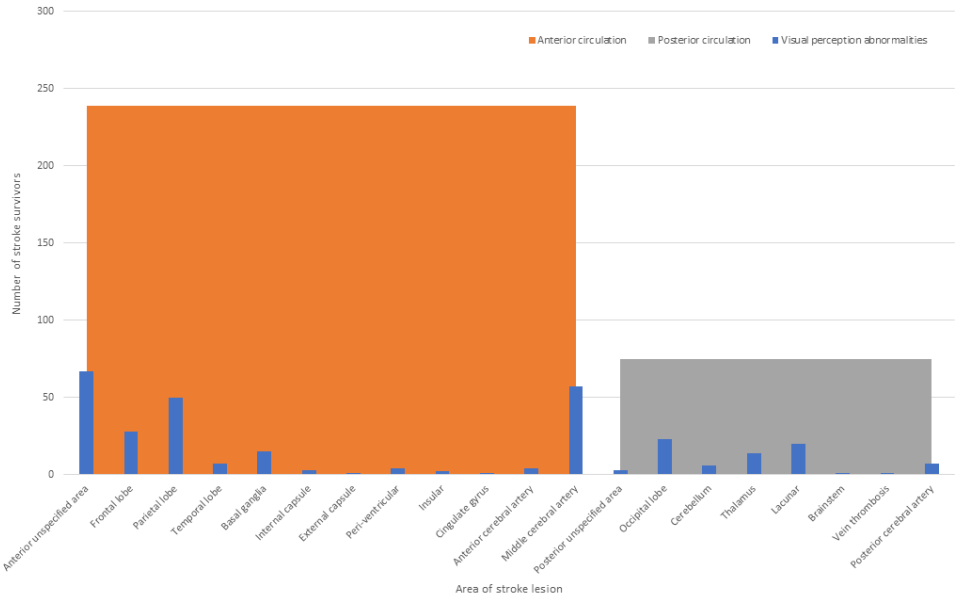


Figure 4, Visual symptoms

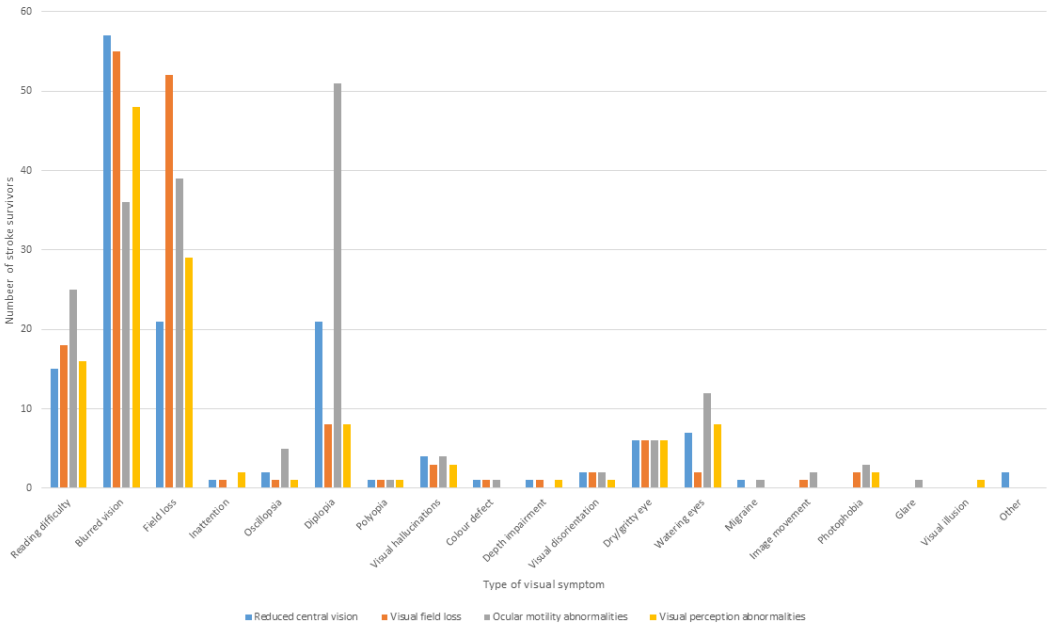
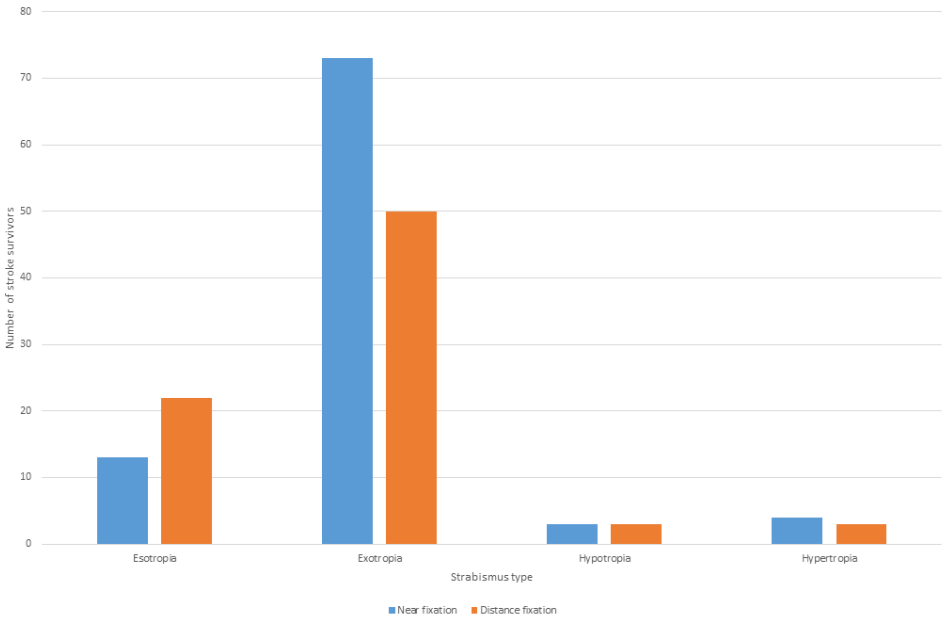
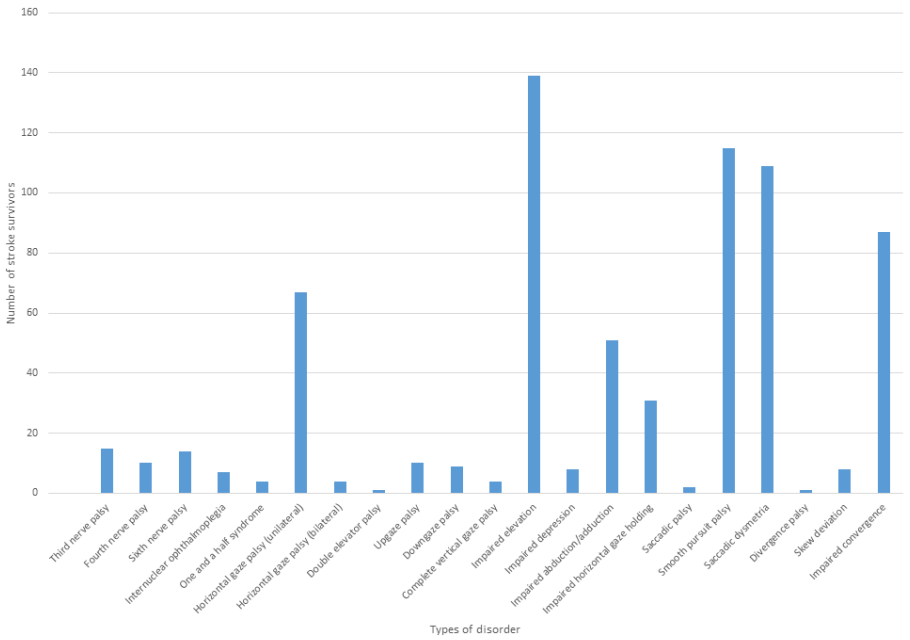


Figure 5, Type of ocular motility abnormality

A, Strabismus



B, Ocular motility disorders



C, Nystagmus

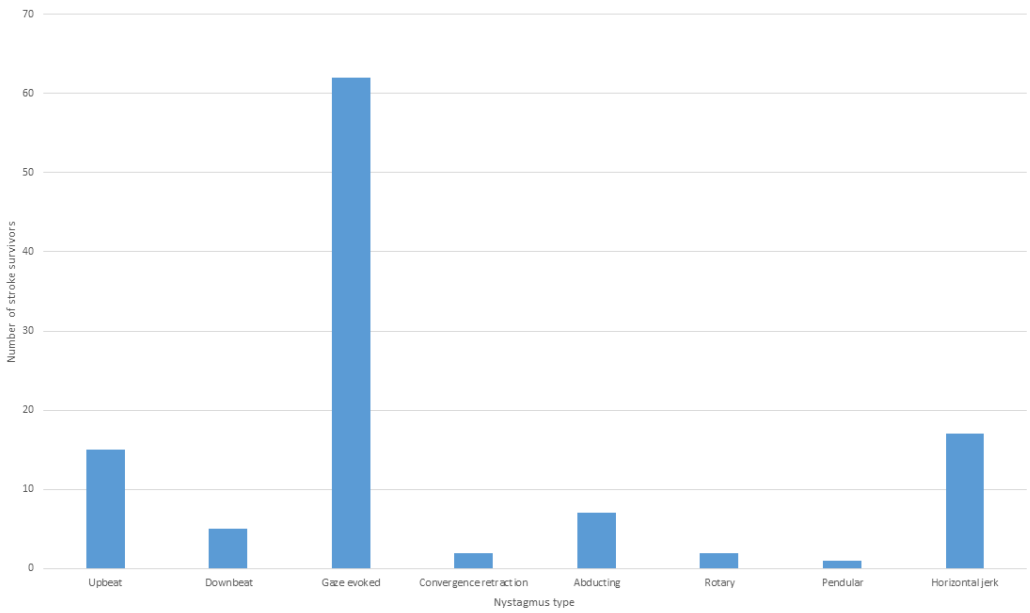


Figure 6, Type of visual perceptual abnormality

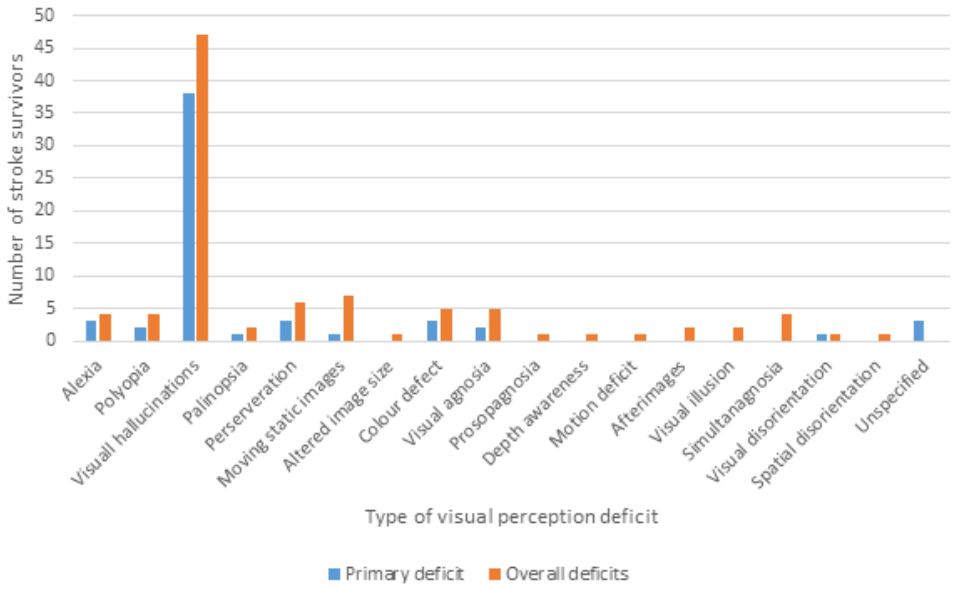


Table 1, Patient demographics

		Never visually assessed	Prior, or no visual impairment	New onset visual impairment
Age: mean (SD)		77.38 (12.39)	69.36 (13.87)	74.33 (13.36)
Barthel: mean (SD)		3.67 (6.56)	14.99 (5.45)	8.58 (7.25)
Gender	Female	170	229	323
	Male	126	273	379
Type	Infarct	220	466	626
	Haemorrhage	75	36	76

Table 2, Visual acuity values

A: Visual acuity level at near;

	Right eye mean, SD	Right eye median; range	Left eye mean, SD	Left eye median; range	Both eyes mean, SD	Both eyes median; range
First test	0.6, 0.356	0.5; 0.1 - 2.5	0.61, 0.483	0.5; 0.04 - 5	0.88, 0.673	0.54; 0.04 - 2.5
Last test	0.45, 0.279	0.4; 0 - 5	0.50, 0.506	0.40; 0 - 5	0.52, 0.433	0.4; 0 – 2

B: VA level at distance;

	Right eye mean, SD	Right eye median; range	Left eye mean, SD	Left eye median; range	Both eyes mean, SD	Both eyes median; range
First test	0.5, 0.562	0.4; 0 - 5	0.53, 0.594	0.38; 0 - 5	0.45, 0.427	0.34; 0 – 5
Last test	0.333, 0.456	0.24; -0.1 - 5	0.436, 0.793	0.24; -0.1 - 5	0.264, 0.37	0.2; -0.1 – 5

Visual acuity was measured using logMAR charts with measurements in numerical increments up to 1.0logMAR. Lower visual acuity measurements were graded as logMAR estimates of 1.5 for 3/60 acuity, 2.0 for hand movements/following face acuity, 2.5 for light perception and 5.0 for no perception of light.

Table 3, Visual field type

Hemianopia			Quadrantanopia			Scotoma	Constriction	Inconsistent responses
	Complete	Partial		Complete	Partial			
Macula sparing	7	96	Superior	5	9	2		41
Macula splitting	109		Inferior	4	11			
Bilateral		4					10	