Title page

Title: Evaluating multidisciplinary glaucoma care: visual field progression and loss of sight year analysis in the community versus hospital setting.

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Running title: Visual field progression in community and tertiary scheme

Conflict of Interest: The authors report no conflict of interest.

ABSTRACT

Background: A variety of shared care models have been developed which aim to stratify glaucoma patients according to risk of disease progression. However, there is limited published data on the rate of glaucoma progression in the hospital versus community setting. Here we aimed to compare rates of glaucomatous visual field progression in the Cambridge Community Optometrist Glaucoma Scheme (COGS) and Addenbrooke's Hospital Glaucoma Clinic (AGC).

Methods: A retrospective comparative cohort review was performed. Patients with 5 or more visual field tests were included. Zeiss Forum software was used to calculate the MD progression rate (dB/year). Loss of sight years (LSY) were also calculated for both COGS and AGC.

Results: 8465 visual field tests from 854 patients were reviewed. 362 eyes from the AGC group and 210 eyes from COGS were included. The MD deterioration rate was significantly lower in the COGS patients compared with the AGC group (-0.1 dB/year vs -0.3 dB/year; $p<0.0001$). No patients in the COGS group were predicted to become blind within their lifetime by LSY analysis. Fifteen patients were at risk in the AGC group.

Conclusion: This service evaluation shows that COGS is an effective scheme to stratify lower risk glaucoma patients, increasing the capacity within HES. COGS patients have a lower rate of visual field deterioration compared to AGC patients. Effective communication between community and tertiary schemes is essential to facilitate transfer of patients requiring further hospital management reliably and efficiently, with the potential for low risk patients to be followed safely in the community.

INTRODUCTION

The lack of capacity in the United Kingdom's hospital eye services (HES) for glaucoma patients has been highlighted in a recent report from the Healthcare Safety Investigation Branch and the award of £3.2 million in compensation by the National Health Service (NHS) to a 34 year old glaucoma patient who went blind due to follow-up delays(1). An estimated 22 people a month suffer severe or permanent loss of sight due to delays in follow-up appointments, and this has also been attributed to insufficient capacity within HES(2). The COVID-19 pandemic has further accelerated the need to manage patients away from HES.

Referral rates for glaucoma suspects and ocular hypertensives also increased following the publication of the initial National Institute for Health and Care Excellence (NICE) guidelines for primary open angle glaucoma (POAG) and ocular hypertension (OHT)(3). The Royal College of Ophthalmologists (RCOphth) issued national guidance to address the anticipated lack of capacity associated with increased referral rates, recommending that a proportion of glaucoma-related NHS HES attendances were contracted to community-based practitioners(4). Community-based care particularly applied to patients being monitored for OHT and suspected

glaucoma to reduce the HES workload; a case mix representing over 30% of HES glaucoma-related visits and over 1 million people in England.

A variety of shared care models have been developed in the UK and overseas which aim to stratify glaucoma patients according to risk of disease progression(5–10). Often, one goal in such schemes is for hospital-based care to be focused on those at higher risk of disease progression where more aggressive treatment may be required to prevent visual disability(11), with lower risk patients managed outside the hospital according to available local expertise and resources. However, there is limited published data on the rate of glaucoma progression in hospital versus community setting for many of these schemes. In the current study, our aim was to conduct a service evaluation to compare rates of glaucomatous visual field progression and loss of sight years in the Cambridge Community Optometrist Glaucoma Scheme (COGS) and Addenbrooke's Hospital Glaucoma Clinic (AGC). The AGC is a tertiary referral centre, but as there is no other hospital serving the local population, the glaucoma clinic for adult patients also functions in a very similar way to other district general hospitals in addition to providing specialist services. We therefore feel that our study is applicable to both secondary and tertiary level services.

The Cambridge Community Optometrist Glaucoma Scheme (COGS)

COGS was established in 2010 and initially used for referral refinement(10). All new referrals to AGC were triaged by a glaucoma specialist nurse into high risk and low risk categories. Those deemed low risk (intraocular pressure (IOP) below 30mmHg or a field defect suspicious of glaucoma or an optic disc suspicious of glaucoma) were assessed in COGS. In 2012, the scheme expanded to monitor ocular hypertensive and glaucoma suspect patients (treated and untreated) and in 2015 it was expanded further to allow the monitoring of patients with early

primary open angle glaucoma, considered low risk for vision loss. In 2019 the scheme widened the inclusion criteria to include more complex and moderate risk glaucoma cases. The current risk stratification guideline used to determine if a patient is suitable for COGS follow-up is outlined in Table 1 below. This guideline is based on an agreed empiric assessment of risk, in conjunction with local stakeholders and clinicians. Changes to the National Institute for Health and Care Excellence guidelines for the diagnosis and management in glaucoma in 2017, including an increased emphasis on optic disc imaging which was not available uniformly in our community clinics, led to a modification of the scheme such that all newly referred patients are now first assessed in AGC with baseline imaging and then referred to the COGS scheme if appropriate.

Patients are examined according to a local protocol using equipment standardised to AGC. Due to a lack of uniform capacity for ocular coherence tomography (OCT) in community optometry practices participating in COGS during the period reported, OCT was not mandated in the COGS clinical assessment, but was performed in the AGC. Participating optometrists complete training in glaucoma under the supervision of a consultant ophthalmologist. They are also required to complete the College of Optometrists Professional Certificate in Glaucoma(12).

Community optometrists have remote access to hospital electronic records and enter all their results in real time. Findings are summarised using a standardised template. All results are reviewed by a consultant ophthalmologist or hospital optometrist within four weeks of the community glaucoma assessment. An outcome letter is generated by the reviewing clinician and copies sent to the GP and patient within six weeks of the community glaucoma assessment.

METHODS

A retrospective comparative cohort review was performed of patients attending the AGC clinic or COGS clinic. All patients had SITA-standard automated perimetry performed with the Humphrey Field Analyzer (HFA, Carl Zeiss Meditec, Dublin, Calif.) using the 24-2 full-threshold programme with a Goldmann size III stimulus and appropriate refractive correction. Patients that had either had one or two eyes with 5 or more SITA-standard 24-2 visual field tests were included in the analysis. All patients from the COGS service since its inception in 2010 to 2019 and a similar cohort from the AGC group were analysed. Data for each eye was processed separately where both eyes were included. The Zeiss Forum software was used to extract the data and calculate the MD progression rate (dB/year) using Guided Progression Analysis. Graphpad Prism software was used for statistical analysis. The D'Agostino-Pearson test was used to evaluate whether the distribution of continuous variables was normal. The descriptive statistics for non-normally distributed variables (number of visual field tests, follow-up, mean deviation rate of progression, loss of sight years) are presented as median (25^{th}-75^{th} percentiles) unless otherwise specified. The Mann-Whitney test was used to compare non-normally distributed independent variables between groups. Loss of sight year (LSY) analysis was performed by estimating the number of years each patient would develop bilateral VF loss worse than MD of −22 dB in their predicted remaining lifetime as previously described(13).

RESULTS

8465 visual field tests from a total of 854 patients were reviewed. 362 eyes from the AGC group and 210 eyes from the COGS group met the eligibility criteria of 5 or more SITA-standard 24-2 visual field tests. All diagnoses and visual field tests performed were included in the analysis (Table 2).

The median MD rates highlighted worsening vision over time in both groups (Table 3). However, the rate of deterioration was significantly lower in the COGS patients compared with the AGC group. (-0.1 dB/year vs -0.3 dB/year; $p<0.0001$).

COGS followed up the majority of patients progressing between 0 to 1 dB per year. 14.3% of patients in the AGC were progressing at a rate greater than 1 dB/year compared to 6.2% in the COGS group. Of the 13 patients in the COGS service that were progressing at greater than 1 dB/year, 11 (87%) had additional non-glaucoma diagnoses that would also affect the visual field. There were no patients in the COGS group deteriorating at rates greater than 3 dB/year.

In general, ocular comorbidities that may have affected the visual field were relatively similar across both groups including age-related macular degeneration (4.4% in AGC vs 2.9% in COGS) and diabetic retinopathy (1.1% in AGC vs 3.8% in COGS). 32.9% of AGC patients had undergone cataract surgery vs 21.4% in COGS.

We also evaluated the visual field loss at the end of the study (Figure 1A-C). We defined early glaucoma as a visual field defect corresponding to a MD of -6 dB or better, moderate glaucoma as an MD between -6 and -12 dB, severe glaucoma as an MD between -12 and -20 dB and end-stage glaucoma as an MD of -20 dB or worse. COGS had a greater proportion of patients with early glaucoma (56.4% in AGC vs 72.9% in COGS) while AGC had a greater proportion of patients with moderate glaucoma (26.5% in AGC vs 13.8% in COGS). Interestingly, there was a similar percentage of patients with severe glaucoma in both groups (11% in AGC vs 10% in COGS). The proportion of patients with end-stage glaucoma in AGC was approximately double that seen in COGS (6.1% vs 3.3%). The proportion of patients in each group who did

not have glaucomatous visual field loss at entry was 16% in AGC and 19.5% in COGS. At the end point of the study, these proportions were 10.2% in AGC and 18.1% in COGS. There was a significant correlation between the visual field loss observed at the end of the study and the rate of MD progression across both groups although the correlation was weaker for COGS patients (Spearman's correlation coefficient r = 0.60 for AGC vs 0.33 for COGS; $p<0.0001$in both groups). No significant correlation was seen between the initial MD and rate of MD progression (Spearman's correlation coefficient r = -0.07 for AGC; p=0.16 vs r = 0.03 for COGS; p-0.66) or the baseline severity between both groups (p=0.15). Figure 1D shows the relationship between initial MD and rate of MD progression across both groups.

The loss of sight year (LSY) analysis was performed in patients from whom data from both eyes was available (Figure 2). This showed a median of 0 years (0-0) in both groups, suggesting that the majority of patients in either group were unlikely to become blind during the course of their lifetime. There were no rapid progressors in the COGS group and no patients in the COGS group were at risk of becoming blind within their lifetime. Fifteen patients were at risk in the AGC group. Weak correlation was seen between the presenting MD and LSY (Spearman's correlation coefficient r = -0.13; p=0.04).

DISCUSSION

COGS was established to help streamline the management of glaucoma in Cambridge, aiming to concentrate higher risk glaucoma patients in AGC and lower risk patients in community clinics. In the current study, there was a significantly greater rate of MD progression in the AGC compared to COGS. No patients were identified as at risk of becoming blind in their lifetime in the COGS group and all rapid progressors (progressing at greater than 3 dB/year) were followed up in AGC. COGS also followed up a greater proportion of slow progressors

(between 0 to 1 dB/year) and 11 of 13 patients in the COGS group progressing at greater than 1 dB/year had other pathologies such as cataract, or coexisting neurological or retinal pathology. One patient from the COGS group progressing at greater than 1 dB/year also requested to remain under the COGS service rather transfer back to AGC.

Ongoing capacity pressures within AGC have led to an increase in the proportion of patients with more advanced glaucoma that are followed within the community scheme over time. This highlights the need for effective communication channels to identify patients requiring further hospital management reliably and efficiently. A recent internal audit conducted at the end of the period of analysis demonstrated that 41% of all patients (45% of moderate risk patients) monitored in COGS were deemed to be unstable at virtual review and required an AGC appointment. Upon review in hospital, the majority of those patients (72%) were correctly identified as unstable and required a change of treatment or closer AGC monitoring.

The widening scope of patients managed in COGS could be considered a strength of the scheme. Rather than exclude this higher risk cohort from community clinics, strategies continue to be developed to manage these patients in the community. The planned transition to virtual amendment of treatment changes by the clinical reviewer with subsequent COGS follow up has the potential to reduce the AGC referral rate. Our risk stratification is based on empiric assessment in conjunction with local stakeholders and clinicians. Alternative stratification methods also include recent tools published by the Royal College of Ophthalmologists (RCOphth) and UK and Eire Glaucoma Society (UKEGS)(14) and the UK Ophthalmology Alliance (UKOA)(15) although it is likely that these guidelines will be tailored according to regional needs and available resources.

LSY analysis was used to help assess the safety of following patients predicted to be at low risk in primary care rather than hospital glaucoma clinics. However, it is important to remember that patients can also suffer a reduced quality of life with an increased risk of falls and other comorbidity due to visual loss before blindness and therefore LSY should not be used as a tool in isolation and the results should be interpreted with caution.

Streamlining and stratifying pathways to facilitate the management of an increasing glaucoma population is essential with community services continuing to grow in response to service need. However, a proportion of patients who have access to regular, high quality care also continue to deteriorate. It is therefore not surprising that patients followed in COGS still have a detectable rate of glaucoma progression.

The overall median rate of deterioration of -0.3 dB/year in AGC and -0.1 dB/year in COGS is comparable to previous reports of glaucoma progression in UK secondary care(16), as is the proportion of patients progressing at a rate greater than 1 dB/year (14.2% in the AGC group). Our rates are lower than those reported from a large tertiary glaucoma service in Sweden (median -0.62 dB/year)(17) , although that population has a higher proportion of patients with pseudoexfoliation glaucoma who are known to have a higher risk of progression(18,19). Another factor contributing to this difference between centres may be that our data was extracted from either eye whereas the Lund authors used data from the eye with the greater visual field defect.

Large multi-centre trials such as the Early Manifest Glaucoma Trial(19) and the United Kingdom Glaucoma Treatment Study(20) also found that a significant proportion of patients in the treatment arms progressed. Moreover, 30-40% or more of glaucoma patients in many

populations show normal tension in IOP measurements(21). In Japan, normal tension glaucoma (NTG) accounts for the majority of patients diagnosed with open-angle glaucoma(22). Although aggressively lowering the IOP by 30% has been shown to reduce the risk of progression for patients with NTG from 35% to 12 % over 5 years, this still means a large number of people will continue to lose vision despite best available current treatment.

The reasons why retinal ganglion cell loss and corresponding visual field deterioration continues despite best treatment are currently unknown, but contributing factors may include insufficient IOP lowering with conventional treatment, poor compliance with intended therapy, or progression despite optimised IOP lowering treatment. A variety of approaches are being undertaken to tackle these problems, from the refinement of medical, laser and surgical approaches to lower the intraocular pressure(23–29), understanding genetic predisposition and the development of personalised medicine(30,31), to new sustained release drug-delivery devices(32) to minimise the effect of poor compliance and the development of neuroprotective strategies as an alternative or adjunct to IOP lowering therapies(33).

Another consideration is the usefulness of OCT scanning in the assessment of glaucoma in the community setting. Abnormalities on OCT scanning of the optic nerve head in subjects over 50 years have been reported to have a false positive glaucoma detection rate of 30%.(34) In another study, focal abnormalities of the retinal nerve fibre layer on spectral domain OCT scanning had a false positive rate of 35%.(35) Furthermore, each OCT technology has different analysis software which is not interchangeable between machines. We therefore did not mandate OCT in the community setting at the time the current scheme was established, although this is currently being reassessed.

For the future, artificial intelligence techniques are playing a key role and their integration into clinical practice has the potential to significantly improve our early detection of at-risk patients and enhance our understanding of the underlying pathophysiology of glaucomatous visual loss(36–38). More accurate endpoints to monitor disease progression and the effects of intervention will also be important(33,39). A number of functional outcome measures are being evaluated in the assessment of glaucoma patients in addition to visual field testing(40–44), from contrast sensitivity(45,46), electrophysiology(47), task completion or simulation(48,49) to patient reported experience of visual loss(50–52).

COGS appears an effective scheme to help manage lower risk glaucoma patients in the UK environment where accredited optometric support can be developed outside of the hospital setting, which increases the capacity within HES to manage higher risk patients. COGS patients have a lower rate of visual field deterioration compared to patients seen in AGC. Effective communication between the community and tertiary schemes is essential to facilitate transfer of patients requiring further hospital management safely and efficiently.

ACKNOWLEDGEMENTS

We would like to thank Dr Susan Bryan and Professor David Crabb, City University for their guidance when performing the loss of sight year analysis and the Cambridge University Hospitals NHS Foundation Trust information analyst team for their technical assistance. No sources of funding to declare.

CONFLICTS OF INTEREST

The authors report no conflicts of interest.

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TITLES AND LEGENDS TO FIGURES

Table 1: *The Cambridge Community Optometry Glaucoma Scheme (COGS)*

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COGS progressors C: LSY in AGC and COGS D: Correlation between initial MD and LSY

Spearman's correlation coefficient r = -0.13; p=0.04)

Table 1 - The Cambridge Community Optometry Glaucoma Scheme (COGS)

Risk	Guideline	Clinician
Low	Family history only/no glaucoma	Discharge
	OHT < 24 mmHg	
	Glaucoma suspect unchanged over 3+ years	
Low	Stable OHT and glaucoma suspect	COGS
	On/off treatment	
	Once baseline imaging completed in HES	
	Includes PDS/PXF	
	POAG (MD < 12 dB), stable on 2 consecutive occasions. Can include post-trabeculectomy > 24 months	
	No dense lens opacity	
	Not on hospital transport or limited mobility	
	Does not require OCT for definitive management	
Low	As for community low risk but requires transport/community not possible due to mobility issues/if regular OCT required	Virtual hospital clinic
Low	Community returns for consideration of discharge	Consultant
Moderate	Secondary glaucoma or OHT	COGS

Risk	Guideline	Clinician
	Angle closure patients	
	Stable moderate to advanced glaucoma (MD > 12 dB), stable on 2 occasions, can include post-trabeculectomy > 12 months	
	Only eye any diagnosis	
	No dense lens opacity	
	Not on hospital transport or limited mobility	
	Does not require OCT for definitive management	
Moderate	Post-laser or medication change	AGC: nurse led
Moderate	Glaucoma progression is suspected	AGC: doctor or optometrist clinics
	Pre- and post-cataract assessments in glaucoma patients	
	Post-op trabeculectomy < 12 months but >2 months	
High	Unstable advanced glaucoma	AGC: consultant slot
	For consideration of surgery	
	Post-op trabeculectomy/tube/other (<2 months)	

Table 2 - Summary statistics

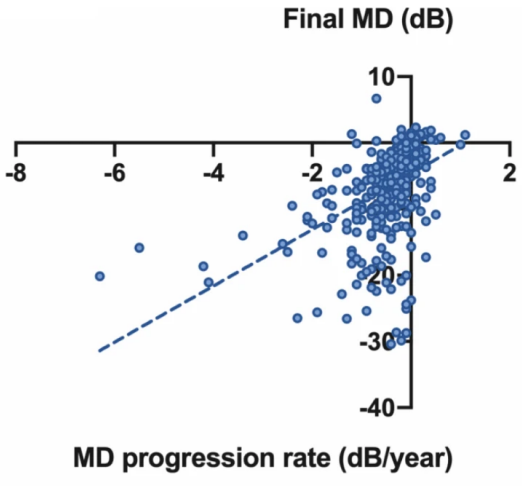
	Tertiary (AGC)	**Community (COGS)**
Number of eyes	362	210
Number of patients	188	119
Age, years (mean ± SEM)	74.8 (±0.80)	69.9 (±0.98)
Gender, *n* (%)		
Male	100 (53.2)	69 (57.9)
Female	88 (46.8)	50 (42.1)
Median number of VF tests	7 (6–10)	6 (5–8)
Median follow-up, years	8 (4–11)	5 (4–8)
Baseline severity MD	−2.43	−2.08
	(−5.8 to −0.8)	(−4.9 to −0.4)
Diagnosis, *n* (%)		
Primary open-angle glaucoma	194 (53.8)	140 (66.2)
Ocular hypertension	39 (10.9)	24 (11.3)
Primary angle closure glaucoma	24 (6.7)	0
Normal tension glaucoma	44 (12.0)	34 (16.4)
Glaucoma suspect	19 (5.3)	4 (1.9)
Secondary open-angle glaucoma	26 (7.2)	4 (1.9)
Neovascular glaucoma	3 (0.8)	2 (0.9)
Uveitic glaucoma	11 (3.1)	3 (1.4)
Juvenile onset glaucoma	1 (0.3)	0

Table 3 - Distribution of MD progression rates

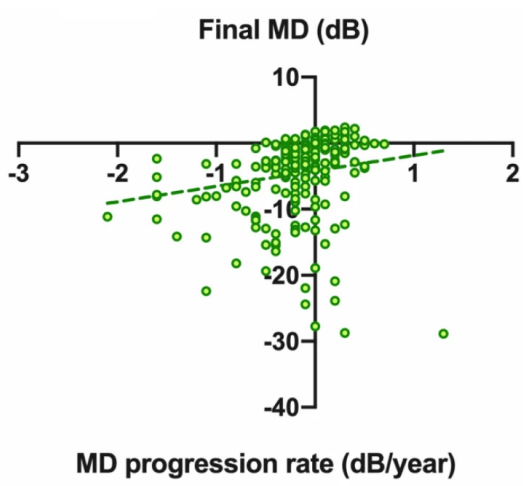
	Tertiary (AGC)	**Community (COGS)**
MD progression dB/yr	−0.3 (−0.7 to 0.0)	−0.1 (−0.4 to 0.1)
Range	−6.3 to 1.1	−2.1 to 1.3
$-0.5 < x \leq -0.1$	134/362 (37.0%)	141/210 (67.1%)
$-1 < x \leq -0.5$	78/362 (21.5%)	27/210 (12.9%)
$-2 < x \leq -1$	40/362 (11.0%)	12/210 (5.7%)
$-3 < x \leq -2$	7/362 (1.9%)	1/210 (0.5%)
$-4 < x \leq -3$	1/362 (0.3%)	0/210 (0%)
$x \leq -4$	4/362 (1.1%)	0/210 (0%)

Figure 1 - Visual field loss and MD progression rate

A



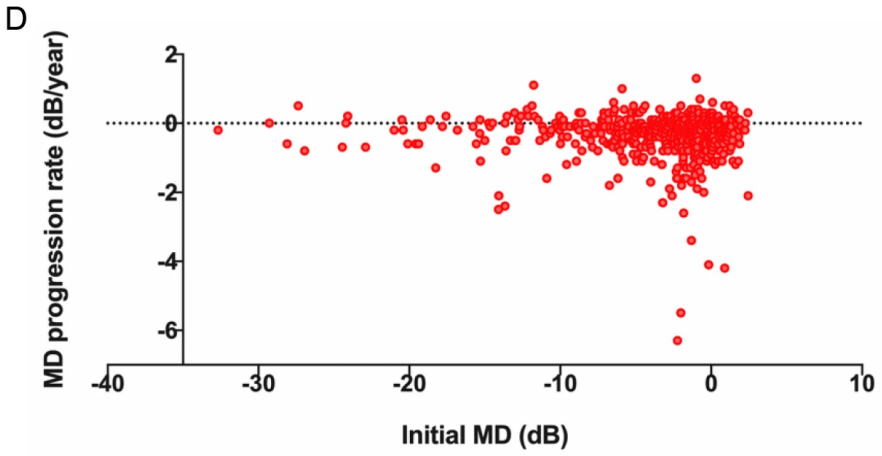
B



C

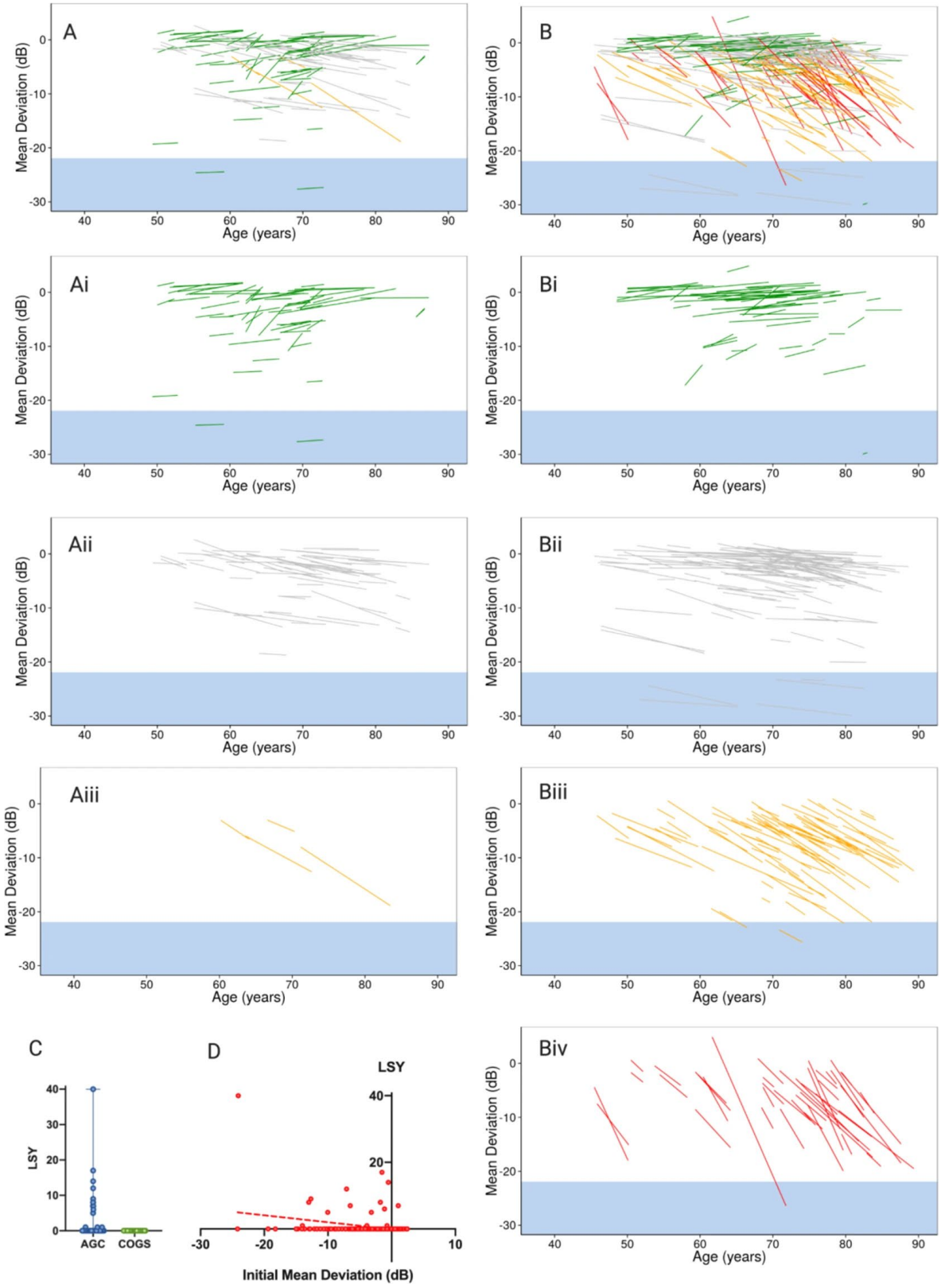
Final MD (dB)	Tertiary (AGC)	Community (COGS)
x ≥ -6	204/362 (56.4%)	153/210 (72.9%)
-12 ≤ x < -6	96/362 (26.5%)	29/210 (13.8%)
-20 ≤ x < -12	40/362 (11.0%)	21/210 (10%)
x < -20	22/362 (6.1%)	7/210 (3.3%)

D



A Relationship between visual field loss at end of study and rate of MD progression in AGC patients. Spearman's correlation coefficient r = 0.60; p < 0.0001. **B** Relationship between visual field loss at end of study and rate of MD progression in COGS patients. Spearman's correlation coefficient r = 0.33; p < 0.0001. **C** Distribution of final MD. **D** Relationship between initial MD and rate of MD progression.

Figure 2 – Loss of sight year (LSY) analysis



A Hedgehog plot for all COGS patients: Ai stable COGS patients, Aii slow COGS progressors, Aiii moderate COGS progressors. **B** Hedgehog plot for all AGC patients: Bi stable AGC patients, Bii slow AGC progressors, Biii moderate AGC progressors Biv rapid AGC progressors. **C** LSY in AGC and COGS. **D** Correlation between initial MD and LSY (Spearman–s correlation coefficient r = −0.13; p = 0.04).