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RETINAL DISORDERS

The effect of ethnicity on anatomic success following macular hole surgery: a multicentre cohort study

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Abstract

Purpose The purpose is to assess the effect of ethnicity on surgical macular hole closure.

Methods A retrospective cohort study was undertaken in five UK National Health Service Hospitals. We included all patients with known ethnicity undergoing vitrectomy, internal limiting membrane peel, and gas/oil tamponade for all stages of primary full-thickness macular hole (FTMH). The primary outcome was anatomic success, defined as FTMH closure with one operation. The secondary outcome was mean change in best-corrected visual acuity (BCVA) comparing baseline with final review.

Results Of 334 operations, the ethnicity profile comprised 78.7% White patients, 11.7% Black patients, 8.1% Asian patients, and 1.5% in mixed/other ethnicities. Mean age was 69.7 years with 68.5% females. Overall, 280 (83.8%) had anatomic success. Anatomic failure occurred in 38.5% of Black patients versus 12.6% of White patients (relative risk: 1.788; 95% CI: 1.012 to 3.159; $P=0.045$). Overall, baseline logarithm of the minimum angle of resolution BCVA improved by 0.34, from 0.95 (95% CI: 0.894 to 1.008) to 0.62 (95% CI: 0.556 to 0.676). Mean BCVA improved by 0.35 in White patients, 0.37 in Black patients, 0.23 in Asian patients, and 0.38 in mixed/other ethnicity ($P=0.689$). Greater FTMH minimum linear diameter was associated with an increased risk of anatomic failure (relative risk: 1.004; 95% CI: 1.002 to 1.005; $P<0.0001$), whereas better pre-operative BCVA (F [1,19] = 162.90; $P<0.0001$) and anatomic success (F [1,19] = 97.69; $P<0.0001$) were associated with greater BCVA improvement. Socio-economic status did not significantly influence anatomic success or BCVA change.

Conclusions Black ethnicity is associated with an approximately twofold greater risk of failed FTMH surgery. The reasons for this difference warrant further study.

Key messages

What was known before

- Better post-operative outcomes for macular hole surgery have been associated with smaller preoperative FTMH base diameter, inner (apical) and minimum linear diameter (MLD).
- Eyes with worse preoperative best-corrected visual acuity (BCVA), older patients, Afro-Caribbean patients and those with a longer duration of symptoms have been identified as independent risk factors for worse rates of anatomic closure and visual improvement.

What this study adds

- This multicentre study of 334 primary macular hole operations found that the risk of anatomic failure was approximately twofold higher for Black British versus White patients.
- There was no significant association between mean change in BCVA and ethnicity.
- Socio-economic status did not significantly influence anatomic success or BCVA change.

Extended author information available on the last page of the article

Keywords Full-thickness macular hole · Pars-plana vitrectomy · Ethnicity

Introduction

Full-thickness macular holes (FTMH) are an important cause of visual loss, particularly in older adults. They have an annual incidence of 8.7 per 100,000 individuals and estimated prevalence of 0.3% and are the second most common indication for vitreoretinal surgery [1–3]. A FTMH is defined as a foveal lesion with interruption of all retinal layers from the internal limiting membrane (ILM) to the retinal pigment epithelium [4]. It is thought that a combination of anteroposterior traction due to perifoveal posterior vitreous detachment and tangential traction via the internal limiting membrane and through contraction of myofibroblasts within epiretinal membranes are key to the pathophysiology of FTMH [2, 5, 6]. Risk factors for the development of primary FTMH include age greater than 65 years, female gender, and myopia [2, 7, 8].

Traditionally, surgical management involves pars plana vitrectomy and intraocular gas tamponade, usually combined with internal limiting membrane (ILM) peel, aiming to close the hole and thereby improve vision [2, 9]. Surgical variables include the use of short or long-acting gas, various techniques of ILM peeling, possible placement of the peeled ILM into the hole, and varying post-operative posturing regimens, depending on the size and chronicity of the macular hole, and both patient and surgeon preference [2]. Intravitreal ocriplasmin is licensed for the treatment of FTMH associated with vitreomacular traction (VMT), but adoption rates are relatively low [10, 11].

Rates of anatomic/surgical success (hole closure) following vitrectomy for primary FTMH range from 81 to 100% [2, 12–14]. Several predictors of surgical success have been reported [2, 13, 14]. Pre-operative FTMH base diameter and inner (apical) and minimum linear diameter (MLD) were associated with both anatomic and visual success [13]. Eyes with better pre-operative best-corrected visual acuity (BCVA), younger patients, and those with a shorter duration of symptoms achieved higher rates of anatomic closure and visual improvement [2, 14, 15].

The aim of the study was to assess the impact of ethnicity on post-operative macular hole closure and vision. We hypothesized that Black British patients had a lower anatomic success rate than White patients.

Materials and methods

Design and setting

A cohort study was conducted in five UK National Health Service vitreoretinal units: King's College Hospital (London), Sunderland Eye Infirmary (Sunderland), Whipps Cross University Hospital (Outer London), Royal Liverpool University Hospital (Liverpool), and the Western Eye Hospital (Central London). Data were retrieved retrospectively using paper and electronic medical records (Medisoft Limited, Leeds, UK) searching for patients undergoing vitrectomy for the indication of FTMH. Data collection included consecutive cases from individual surgeons carried out over variable time periods from June 2008 to March 2020.

Ethics statement

This study adhered to the revised Declaration of Helsinki (2008). The study used non-identifiable data collected during the course of routine clinical practice and was therefore determined to be an audit (audit registration: JBJEHX27C8) by the King's College Hospital NHS Foundation Trust Research & Development and Audit teams. Accordingly, Research Ethics Committee approval was not required [16].

Eligibility

Patients with recorded ethnicity undergoing pars plana vitrectomy, ILM peel, and gas/oil tamponade for all stages of primary FTMH were included [4]. Eyes with a history of trauma, uveitis, high myopia (≥ 8 dioptres or axial length ≥ 26 mm), FTMH in association with other significant retinal disease, previous retinal surgery, ocriplasmin treatment, current anti-vascular endothelial growth factor treatment, less than 3 months' follow-up, inadequate imaging, cataract surgery 3 months' prior to PPV, lamellar holes, and pseudo-holes were excluded. Eyes with co-existing epiretinal membrane were not excluded. In eyes with bilaterally eligible surgery, the first eye surgery was selected.

Outcome measures

The primary outcome was anatomic success (FTMH closure) at final review, without the need for repeat macular hole surgery. Hole closure was determined using spectral domain optical coherence tomography (OCT) and defined as an absence of any full-thickness foveal neurosensory retinal defect. The secondary outcome was mean change in pre-operative versus final BCVA.

Data collection

The following data were collected from the medical records: age, gender, ethnicity, postcode, pre-operative BCVA, macular hole base diameter (μm), and minimum linear diameter (μm) using the scan with minimum hole diameter, macular pathology including presence or absence of VMT, surgical procedure including techniques used such as phaco-vitrectomy and tamponade agent, post-operative posturing regimen, FTMH closure, and post-operative BCVA.

Analysis and statistics

The main 'exposure' was ethnicity, which was self-reported and divided into four groups based on the 16 categories utilized in the UK national census: White (British, Irish, any other White background), Black (Caribbean, African, any other Black background), Asian (Indian, Pakistani, Bangladeshi, Chinese, any other Asian background), and mixed/other (White and Black Caribbean, White and Black African, White and Asian, any other mixed background, any other Ethnic group) [17].

The effect of ethnicity on anatomic success/failure and BCVA were adjusted for age, gender, socio-economic status, pre-operative BCVA, presence or absence of VMT, FTMH base diameter, and minimum linear diameter, and surgical technique including combined phaco-vitrectomy, tamponade agent, and post-operative posturing regimen. This model aimed to incorporate core demographic variables, reported predictors of anatomic success, and key confounding variables [2, 8, 13–15]. Although duration of macular hole has been reported to predict surgical failure it was not used, as it is often hard to verify duration of disease, especially with uniocular FTMHs in the non-dominant eye [2, 14, 18].

The International Vitreomacular Traction Study (IVTS) Group classification was used, wherein FTMHs are categorized by the presence or absence of VMT and size: as small (< 250 μm), medium (> 250 μm and < 400 μm), and large (> 400 μm), based on the horizontally measured linear width at the narrowest point of the hole [4].

Pre-operative and post-operative BCVA were recorded using the logarithm of the minimum angle of resolution (logMAR) scale. Any BCVAs recorded using other means were converted to logMAR, with counting fingers (CF), hand motion (HM), and light perception (LP) assigned scores of 2.1, 2.4 and 2.7, respectively [9, 19].

Socio-economic status was based on individual postcodes utilizing the Index of Multiple Deprivation (IMD 2019), which provides a relative ranking of areas across the country according to their level of deprivation, with lower rank indicating a higher level of deprivation. The IMD ranks were grouped according to quintile for the purpose of analysis [20].

Data were analyzed using Stata 14.1 (StataCorp, Texas, USA) software. Analyses were performed using the Pearson's chi-squared test, Student's *t* test, and analysis of variance (ANOVA). Multivariate analysis was carried out to measure the effect of ethnicity on anatomic success/failure and BCVA and adjusted for key confounding variables, using Poisson regression with robust standard errors and analysis of covariance (ANCOVA), respectively.

Results

Of 344 eligible patients, the mean age was 69.7 years, 228 (68.5%) were female, 263 (78.7%) defined themselves as White, 39 (11.7%) Black, 27 (8.1%) Asian, and 5 (1.5%) mixed/other (Table 1). The overall distributions of IMD quintiles are provided in Table 1. The distribution according to ethnicity was unequal ($P = 0.057$), with 24.6% of White patients in the higher quintiles (least deprived areas IMD quintiles 4–5), 7.9% of Black patients, 18.5% of Asian patients, and 0.0% in mixed/other ethnic group. The proportion of White patients in the lower quintiles (most deprived areas IMD quintiles 1–2) was 50.5%, Black patients 79%, Asian patients 55.5%, and 60% of mixed/other ethnicities.

The overall mean pre-operative logMAR BCVA was 0.95 (Snellen equivalent $6/60^{+1}$; 95% CI: 0.894 to 1.008; range: 0.12 to 2.40). Mean pre-operative logMAR BCVA according to ethnicity was 0.93 in White patients, 1.11 in Black patients, 0.93 in Asian patients, and 0.94 in mixed/other ethnic group ($P = 0.236$) (Supplemental material available online only). The overall mean macular hole MLD was 420.4 μm (95% CI: 400.6 to 440.2; range: 31 to 1137). Minimum linear diameter in White patients was 409.4 μm, 472.4 μm in Black patients, 451.0 μm in Asian patients, and 428.6 μm in mixed/other ($P = 0.184$). The overall mean macular hole base diameter was 906.6 μm (95% CI: 866.2 to 947; range: 179 to 3734). Base diameter in White patients was 890.2 μm, 973.6 μm in Black patients, 943.9 μm in Asian patients, and 1048.4 μm in mixed/other ($P = 0.440$). Overall, 22.8% of patients had VMT at the time of surgery however there was no significant difference between ethnicities and the presence of VMT ($P = 0.955$).

Anatomic success

Of 334 FTMH surgeries, 280 (83.8%) had anatomic success (Table 2). Anatomic failure occurred in 12.6% of White patients, 38.5% of Black patients, 18.5% of Asian patients, and 20% in mixed/other ethnic group ($P = 0.001$). Of the 54 persisting macular holes, 34 cases went on to have a second FTMH surgery including 20 White patients, 10 Black patients, and 4 Asian patients. Of these cases, 12 cases closed (35.3%), 2 were partially closed (5.9%) and 20 cases remained open (58.8%) including 9 White, 9 Black, and 2 Asian patients. Five cases had a third surgery including 2 White patients, 2 Black patients, and 1 Asian patient, and all remained open.

Of the 10 cases with Black ethnicity that went on to have a second surgery, the 1 case that closed successfully following surgery had a macular hole apex diameter of 172 µm and a base diameter of 230 µm. The other remaining cases had larger apex and base diameters ranging from 252 to 822 µm and 551 to 1453 µm, respectively.

We carried out Poisson regression to determine the effect of ethnicity on macular hole closure, adjusted for key confounding variables (Table 3). Black ethnicity was an independent risk factor for surgical failure (relative risk: 1.788; 95% CI: 1.012 to 3.159; $P=0.045$), as was macular hole MLD (relative risk: 1.004; 95% CI: 1.002 to 1.005; $P<0.0001$). The mean baseline MLD in those who achieved primary MH closure was 392.9 µm, compared to 562.9 µm in those who did not.

Table 1 Baseline characteristics and surgical procedures

	Mean (95% CI)
Age	69.7 (68.7 to 70.6)
Baseline BCVA	0.95 (0.9 to 1.0)
Post-operative BCVA	0.62 (0.6 to 0.7)
Gender	*n* (%)
Male	105 (31.5)
Female	228 (68.5)
Ethnicity	*n* (%)
White	263 (78.7)
Black	39 (11.7)
Asian	27 (8.1)
Mixed/other	5 (1.5)
Index of multiple deprivation quintiles	*n* (%)
1 (most deprived area)	79 (23.9)
2	100 (30.3)
3	79 (23.9)
4	43 (13.0)
5 (least deprived area)	29 (8.8)
Macular hole size	Mean (95% CI)
Base (µm)	906.6 (866.2 to 947.1)
MLD (µm)	420.4 (400.6 to 440.2)
Vitreomacular traction	*n* (%)
No	258 (77.3)
Yes	76 (22.8)
Combined phaco-vitrectomy	*n* (%)
No	200 (59.9)
Yes	134 (40.1)
Endotamponade agent	*n* (%)
SF_6	65 (19.8)
C_2F_6	79 (24.1)
C_3F_8	183 (55.8)
Silicone oil	1 (0.3)
Posturing regimen	*n* (%)
None	1 (0.3)
1–7 days	302 (91.9)
> 7 days	25 (7.8)

CI, confidence interval; *BCVA*, best-corrected visual acuity; *IMD*, index of multiple deprivation; *MLD*, minimum linear diameter; SF_6, sulfur hexafluoride; C_2F_6, perfluorethane; C_3F_8, perfluorpropane

Visual acuity

The mean post-operative logMAR BCVA at final review was 0.62 (95% CI: 0.556 to 0.676 and range: −0.18 to 2.70), demonstrating a 0.34 logMAR improvement from baseline (95% CI: 0.28 to 0.41; range: −2.10 to 1.92). Figure 1 compares pre-operative with post-operative BCVA (logMAR) according to ethnicity. The mean post-operative improvement in logMAR BCVA according to ethnicity included an improvement of 0.35 in White patients, 0.37 in Black patients, 0.23 in Asian patients and 0.38 in Mixed/ Other ethnicity ($P=0.689$). The mean post-operative logMAR BCVA according to ethnicity was 0.58 in White patients, 0.74 in Black patients, 0.71 in Asian patients, and 0.54 in mixed/other ethnicity ($P<0.0001$).

We used analysis of covariance to determine the effect of all variables on mean post-operative change in BCVA. The model included the same independent variables as for Poisson regression. There was no significant association between mean change in BCVA and ethnicity (F [3, 19] = 0.91; $P=0.4368$) or IMD quintiles (F [4, 19] = 0.10; $P=0.9839$). Macular hole closure (F [1, 19] = 97.69; $P<0.0001$) and better pre-operative BCVA (F [1, 19] = 162.90; $P<0.0001$) were significantly associated with mean post-operative visual improvement.

Discussion

Our study investigated the impact of ethnicity on macular hole closure rates and visual outcome following primary surgery. Black patients had an approximately twofold greater chance of failed surgery versus White patients. This difference remained statistically significant (relative risk: 1.788; 95% CI: 1.012 to 3.159; $P=0.045$) despite adjustment for pre-defined core demographic variables and key confounding variables including FTMH size and socio-economic status. Despite a lower success rate, the mean change in final BCVA was not significantly different in Black vs White patients.

Several studies have demonstrated inter-ethnic variation in foveal morphology including deeper, broader, and larger volume foveal pits, thinner central macular and foveal thickness, and thinner inner retina in eyes of Black patients compared to their White and Asian counterparts [21–23]. It is therefore conceivable that a difference in foveal morphology could be a contributing factor to poorer surgical outcomes.

Table 2 Post-operative macular hole (MH) status according to baseline characteristics and surgical techniques

	Macular hole open		Macular hole closed		
	n	Mean (CI)	*n*	Mean (CI)	*P* value
Mean age	54	69.6 (58.8–80.5)	280	69.7 (61.4–77.9)	0.563
Mean baseline BCVA	54	1.13 (0.5–1.8)	280	0.92 (0.4–1.4)	0.006
Mean post-operative BVCA	54	1.39 (0.6–2.2)	280	0.47 (0.1–0.8)	< 0.001
Gender	*n* (%)		*n* (%)		
Male	19 (18.1)		86 (81.9)		0.471
Female	34 (15.0)		194 (85.0)		
Ethnicity	*n* (%)		*n* (%)		
White	33 (12.6)		230 (87.5)		0.001
Black	15 (38.5)		24 (61.5)		
Asian	5 (18.5)		22 (81.5)		
Mixed/other	1 (20.0)		4 (80.0)		
IMD quintiles	*n* (%)		*n* (%)		
1 (most deprived area)	13 (16.5)		66 (83.5)		0.852
2	19 (19.0)		81 (81.0)		
3	13 (16.5)		66 (83.5)		
4	5 (11.6)		38 (88.4)		
5 (least deprived area)	4 (13.8)		25 (86.2)		
Macular hole size	*n*	Mean (CI)	*n*	Mean (CI)	
Base (µm)	54	1125.8 (525.7–1725.9)	280	864.4 (565.6–1163.2)	< 0.001
MLD (µm)	54	562.9 (366.5–759.4)	280	392.9 (225.0–560.8)	< 0.001
Vitreomacular traction	*n* (%)		*n* (%)		
No	43 (16.7)		214 (83.3)		0.648
Yes	11 (14.5)		65 (85.5)		
Combined phaco-vitrectomy	*n* (%)		*n* (%)		
No	40 (20.0)		160 (80.0)		0.020
Yes	14 (10.5)		120 (89.6)		
Endotamponade agent	*n* (%)		*n* (%)		
SF_6	7 (10.8)		58 (89.2)		< 0.001
C_2F_6	1 (1.3)		78 (98.7)		
C_3F_8	43 (23.5)		140 (76.5)		
Silicone oil	1 (100.0)		0 (0.0)		
Posturing regimen	*n* (%)		*n* (%)		
None	0 (0.0)		1 (100.0)		
1–7 days	47 (15.6)		254 (84.4)		0.497
> 7 days	6 (24.0)		19 (76.0)		

BCVA, best-corrected visual acuity; *IMD*, index of multiple deprivation; *MLD*, minimum linear diameter; SF_6, sulfur hexafluoride; C_2F_6, perfluorethane; C_3F_8, perfluorpropane

Murphy et al. recently reported that Afro-Caribbean and Asian patients had significantly larger foveal floor widths than White patients. They found that foveal floor width of the fellow eye, in patients with a unilateral macular hole, correlated significantly with macular hole size [24].

Wickham et al. also found Afro-Caribbean ethnicity and hole diameter to be independent risk factors for surgical failure, and although not measured directly in their study, they proposed that the presence of more pre-existing vitreoretinal traction could be a contributing factor [25]. They referred to another study that noted that Afro-Caribbean patients undergoing vitrectomy for complications of diabetes have broader and more anterior vitreoretinal adhesions [26]. Although we did not explore the extent of vitreoretinal adhesions we found that there was no significant difference in the presence or absence of VMT and FTMH closure rate or ethnicity. A more recent study by Mastropasqua et al. reported a loss of vision and poorer anatomic outcomes in Black patients following delamination surgery for traction complications of proliferative diabetic retinopathy; they also attributed this

Table 3 Multivariate analysis model of variables predicting macular hole closure

	IRR	Robust SE	z	P	95% CI
Ethnicity (versus White)					
Black	1.788	0.519	2.00	0.045	1.012 to 3.159
Asian	0.762	0.346	− 0.60	0.550	0.313 to 1.856
Mixed/other ethnicity	1.321	1.168	0.32	0.753	0.233 to 7.473
Age	1.012	0.018	0.69	0.489	0.978 to 1.048
Gender (versus male)					
Female	0.687	0.178	− 1.45	0.148	0.414 to 1.142
Pre-op BCVA logMAR	1.125	0.295	0.45	0.654	0.673 to 1.880
IMD quintiles					
2	1.023	0.323	0.07	0.944	0.551 to 1.898
3	1.279	0.481	0.65	0.513	0.612 to 2.674
4	1.183	0.632	0.31	0.754	0.415 to 3.372
5	1.059	0.466	0.13	0.897	0.447 to 2.509
Vitreomacular traction	1.056	0.426	0.14	0.892	0.479 to 2.328
Macular hole base (µm)	1.000	0.000	1.65	0.099	0.999 to 1.001
Macular hole MLD (µm)	1.004	0.001	5.2	0.000	1.002 to 1.005
Combined phaco-vitrectomy	0.653	0.177	− 1.57	0.116	0.384 to 1.111
Endotamponade agent (versus C_3F_8)					
SF_6	1.155	0.44	0.38	0.705	0.548 to 2.436
C_2F_6	0.072	0.071	− 2.68	0.007	0.011 to 0.495
Silicone Oil	12.183	8.486	3.59	0.000	3.111 to 47.714
Posturing regimen (1–7 days)					
> 7 days	1.519	0.615	1.03	0.301	0.687 to 3.360

BCVA, best-corrected visual acuity; *IMD*, index of multiple deprivation; *MLD*, minimum linear diameter; *SF_6*, sulfur hexafluoride; *C_2F_6*, perfluorethane; *C_3F_8*, perfluorpropane

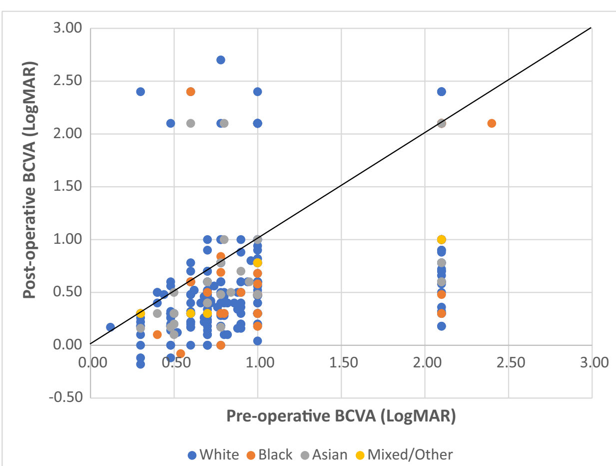

Fig. 1 Pre-operative versus post-operative best-corrected visual acuity according to ethnicity. The line of equality represents no change in best-corrected visul acuity (BCVA), with the points below the line indicating improved BCVA and those above the line indicating reduced post-operative BCVA. The following logarithm of the minimum angle of resolution (logMAR) values were assigned for: counting fingers 2.1 ($n=50$ pre-operatively; $n=23$ post-operatively); hand motion 2.4 ($n=1$ pre-operatively; $n=7$ post-operatively); light perception 2.7 ($n=0$ pre-operatively; $n=1$ post-operatively)

finding to stronger vitreo-retinal adhesions thereby rendering surgical delamination technically more difficult [27]. However, a subsequent study by Ho et al., investigating the outcome of surgery on a similar cohort of Black patients found that improvement in vision was comparable to outcomes from the UK National Ophthalmic Database report [28]. They found that pre-operative visual acuity and use of silicone oil significantly predicted visual decline at 6 months and suggested that silicone oil should be avoided in these patients if possible.

While there was a non-significant difference between macular hole MLD according to ethnicity, with Black patients demonstrating a larger diameter, it is not clear if this is an indication of chronicity and possible delay in presentation or due to a difference in macular morphology resulting in a larger macular hole. FTMH chronicity has been shown to be an important risk factor for surgical failure, with reported reduced rates of FTMH closure in durations greater than 1 year [2, 14, 18]. Unfortunately, due to the retrospective nature of the study and the inherent uncertainties in patient awareness of uniocular vision loss, it was not possible to collect consistent and reliable data on chronicity and duration of symptoms.

Our data suggest that a higher proportion of Black and Asian patients were of lower socio-economic status than White patients. Despite this, socio-economic status was not an independent risk factor for anatomic failure following FTMH surgery. A number of studies have highlighted that individuals from minority ethnic groups and people with lower socio-economic status are less likely to access eye care services, and more likely to present late, with more advanced disease [29–31]. Further research to explore the relationship between ethnicity, socio-economic status, timing of presentation, delay in offering or receiving surgery, and FTMH closure would be useful.

The primary aim of any intervention in patients with FTMH is to release the residual vitreomacular adhesions and traction, thereby restoring normal macular architecture and closing the FTMH [5]. Peeling of the ILM has been shown to improve closure rates which has been attributed to a number of mechanisms including removal of the residual vitreous cortex and fibro-cellular associations, removal of the rigid and less compliant ILM (relative to the retina itself), and increasing retinal glial cell proliferation [2, 32]. Gas is used to facilitate hole closure by preventing trans-hole fluid flow from the vitreous cavity due to gas surface tension while also acting as a surface to allow glial cell migration to bridge the gap between the retinal edges [2, 32]. It is possible that many of these mechanisms of FTMH repair may be compromised in the presence of reduced retinal compliance or redundancy, whether due to chronicity or inter-ethnic variation in fovea morphology. Further modified surgical techniques such as macular detachment or ILM manipulation techniques may be a consideration in this setting [33].

Other studies have described inter-ethnic variation in scleral thickness and compliance in donor samples and greater displacement of the lamina cribrosa in elevated intra-ocular pressure [34, 35]. The impact of these findings on FTMH surgery are yet to be explored but it does raise possible questions regarding the efficacy of tamponade and wound integrity in this setting. Other potential areas to explore include the efficacy of ILM stain and adequate ILM peel in Black eyes and compliance with posturing. While the majority of cases will have been advised to undertake post-operative facedown posturing (1–7 days in 91.9% of cases and > 7 days 7.8%), due to the retrospective nature of the study it has not been possible to accurately measure compliance.

Interestingly, the lower MH closure rates in Black patients was not associated with a significantly smaller gain in vision. Specifically, there was no significant association between mean change in BCVA and ethnicity ($P = 0.689$), or IMD quintiles ($P = 0.5851$). The reason for this is uncertain. Possibly, due to a worse baseline BCVA, Black patients had greater potential for visual gain from macular hole closure that counteracts the worse closure rate, whereas the vision in those that did not close remained poor but stable. By contrast, White patients seemed to have greater potential for vision loss if the macular hole remained open, perhaps pointing to macular holes of shorter duration.

While there was a significant difference in final post-operative BCVA according to ethnicity on univariate analysis, with White patients demonstrating a better final BCVA, the significance was not upheld on multivariate analysis. To our knowledge, there are no reports in the literature that have investigated the relationship between ethnicity and post-operative visual outcome for FTMH repair. In keeping with our data, most studies have found visual outcomes are dependent on macular hole closure and pre-operative BCVA ($P < 0.001$) [14].

Limitations of this study include its retrospective nature, but it is a suitable design for describing associations (rather than causal links). We elected not to quantify FTMH duration, as that information is not always reliably recalled or documented, but hole duration could be a relevant confounding variable as long-standing macular holes are more difficult to close. Placement of peeled ILM into the FTMH was seldom undertaken at the time of our study but may have become more common since. There was no standardization of surgical techniques including gas selection and it has not been possible to accurately assess compliance with post-operative posturing however the use of real-world data enhances generalizability.

In conclusion, this cohort has demonstrated that Black ethnicity is associated with an approximately twofold greater risk of failed FTMH surgery. The reasons for this difference warrant further study. Neither ethnicity nor IMD quintile were found to be associated with a better or worse post-operative visual outcome.

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Author contribution Substantial contributions to the conception were provided by TLJ, HL, and EP. Design of the work was provided by TLJ, HL, EP, LM, AD, HZ, TS, and DHS. Acquisition was done by HL, CB, LM, MR, ND, BZ, GKL, OT, HZ, TS, DHS, VK, CM, RZ, and GD. Analysis was done by HL and AD and interpretation of data for the work was done by HL, TLJ, and AD. Drafting the work or revising it critically for important intellectual content was done by all authors. Final approval of the version to be published was provided by all authors. Agreement to be accountable for all aspects of the work was provided by all authors.

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Declarations

Ethical approval The study used non-identifiable data collected during the course of routine clinical practice and was therefore determined to be an audit (audit registration: JBJEHX27C8) by the King's College Hospital NHS Foundation Trust Research & Development and Audit teams. Accordingly, Research Ethics Committee approval was not required.

Informed Consent The study used non-identifiable data collected during the course of routine clinical practice.

Conflict of interest The authors declare no competing interests.

References

1. McCannel CA, Ensminger JL, Diehl NN, Hodge DN (2009) Population-based incidence of macular holes. Ophthalmology 116(7):1366–1369
2. Madi HA, Masri I, Steel DH (2016) Optimal management of idiopathic macular holes. Clin Ophthalmol 10:97–116
3. Jackson TL, Donachie PH, Sparrow JM, Johnston RL (2013) United Kingdom National Ophthalmology Database Study of Vitreoretinal Surgery: report 1; case mix, complications, and cataract. Eye (Lond) 27(5):644–651
4. Duker JS, Kaiser PK, Binder S et al (2013) The International Vitreomacular Traction Study Group classification of vitreomacular adhesion, traction, and macular hole. Ophthalmology 120(12):2611–2619
5. Steel D, Lotery AJ (2013) Idiopathic vitreomacular traction and macular hole: a comprehensive review of pathophysiology, diagnosis, and treatment. Eye 27:S1–S21
6. Wilczyński T, Heinke A, Niedzielska-Krycia A, Jorg D, Michalska-Małecka K (2019) Optical coherence tomography angiography features in patients with idiopathic full-thickness macular hole, before and after surgical treatment. Clin Interv Aging 14:505–514
7. Singh AJ, Muqit MMK, Woon WH (2012) Is axial length a risk factor for idiopathic macular hole formation? Int Ophthalmol 32(4):393–396
8. Evans JR, Schwartz SD, McHugh JDA et al (1998) Systemic risk factors for idiopathic macular holes: a case-control study. Eye 12(2):256–259
9. Jackson TL, Donachie PHJ, Sparrow JM, Johnston RL (2013) United Kingdom National Ophthalmology Database Study of Vitreoretinal Surgery: report 2, macular hole. Ophthalmol 120(3):629–634
10. Stalmans P, Benz MS, Gandorfer A et al (2012) MIVI-TRUST Study Group. Enzymatic vitreolysis with ocriplasmin for vitreomacular traction and macular holes. N Engl J Med 16 367(7):606–15
11. Singh R, Stone T (2018) Global Trends in Retina Survey: 13 Chicago, IL. American Society of Retina Specialists; 2018. www.asrs.org/content/documents/2018-global-trends-in-retina-survey-highlights-website.pdf Accessed July 30, 2021
12. Ezra E, Gregor ZJ (2004) Moorfields Macular Hole Study Group Report No. 1. Surgery for idiopathic full-thickness macular hole: two-year results of a randomized clinical trial comparing natural history, vitrectomy, and vitrectomy plus autologous serum: Moorfields Macular Hole Study Group Report no. 1. Arch Ophthalmol 122(2):224–36
13. Wakely L, Rahman R, Stephenson J (2012) A comparison of several methods of macular hole measurement using optical coherence tomography, and their value in predicting anatomical and visual outcomes. Br J Ophthalmol 96(7):1003–1007
14. Steel DH, Donachie PHJ, Aylward GW, Laidlaw DA, Williamson TH, Yorston D (2021) BEAVRS Macular hole outcome group. Factors affecting anatomical and visual outcome after macular hole surgery: findings from a large prospective UK cohort. Eye 35(1):316–325
15. Gupta B, Laidlaw DA, Williamson TH, Shah SP, Wong R, Wren S (2009) Predicting visual success in macular hole surgery. Br J Ophthalmol 93(11):1488–1491
16. NHS Research authority. Medical Research Council. http://www.hra-decisiontools.org.uk/research/ Accessed July 30, 2021
17. Office for National Statistics. National Census Data. https://www.ons.gov.uk/census Accessed July 30, 2021
18. Murphy D, Al-Zubaidy M, Lois N, Scott N, Steel DH, Macular Hole Duration Study Group (2022) The effect of macular hole duration on surgical outcomes. An individual participant data study of randomized controlled trials. Ophthalmology. https://doi.org/10.1016/j.ophtha.2022.08.028
19. Sparrow JM, Taylor H, Qureshi K, Smith R, Birnie K, Johnston RL, UK EPR user group (2012) The Cataract National Dataset electronic multi-center audit of 55,567 operations: risk indicators for monocular visual acuity outcomes. Eye 26(6):821–826
20. Ministry of Housing, Communities & Local Government. English indices of deprivation 2019. http://imd-by-postcode.opendatacommunities.org/imd/2019. Accessed July 30, 2021
21. Wagner-Schuman M, Dubis AM, Nordgren RN et al (2011) Race- and sex-related differences in retinal thickness and foveal pit morphology. Invest Ophthalmol Vis Sci 52(1):625–634
22. Girkin CA, McGwin G Jr, Sinai MJ et al (2011) Variation in optic nerve and macular structure with age and race with spectral-domain optical coherence tomography. Ophthalmology 118(12):2403–2408
23. Zouache MA, Silvestri G, Amoaku WM et al (2020) Comparison of the morphology of the foveal pit between African and Caucasian populations. Transl Vis Sci Technol 9(5):24
24. Murphy DC, Melville HJR, George G et al (2021) The association between foveal floor measurements and macular hole size. Ophthalmol Retina 5(7):680–686
25. Chandra A, Lai M, Mitry D et al (2017) Ethnic variation in primary idiopathic macular hole surgery. Eye 31(5):708–712
26. Yorston D, Wickham L, Benson S, Bunce C, Sheard R, Charteris D (2008) Predictive clinical features and outcomes of vitrectomy for proliferative diabetic retinopathy. Br J Ophthalmol 92(3):365–368
27. Mastropasqua R, Luo YH, Cheah YS, Egan C, Lewis JJ, da Cruz L (2017) Black patients sustain vision loss while White and South Asian patients gain vision following delamination or segmentation surgery for tractional complications associated with proliferative diabetic retinopathy. Eye 31(10):1468–1474
28. Ho J, Williamson TH, Wong RS, Laidlaw DAH (2009) Beneficial visual outcome of vitrectomy and delamination surgery for tractional complications of diabetic retinopathy in a cohort of black patients. Eye 33(12):1884–1889

29. Hamm LM, Black J, Burn H et al (2020) Interventions to promote access to eye care for non-indigenous, non-dominant ethnic groups in high-income countries: a scoping review protocol. BMJ Open 10(6):e033775
30. Kirthi V, Reed KI, Gunawardena R, Alattar K, Bunce C, Jackson TL (2021) Do Black and Asian individuals wait longer for treatment? A survival analysis investigating the effect of ethnicity on time-to-clinic and time-to-treatment for diabetic eye disease. Diabetologia 64(4):749–757
31. Leamon S, Hayden C, Lee H et al (2014) Improving access to optometry services for people at risk of preventable sight loss: a qualitative study in five UK locations. J Public Health (Oxf) 36(4):667–673
32. Smiddy WE, Flynn HW Jr (2004) Pathogenesis of macular holes and therapeutic implications. Am J Ophthalmol 137(3):525–537
33. Ittarat M, Somkijrungroj T, Chansangpetch S, Pongsachareonnont P (2020) Literature review of surgical treatment in idiopathic full-thickness macular hole. Clin Ophthalmol 30(14):2171–2183
34. Fazio MA, Johnstone JK, Smith B, Wang L, Girkin CA (2016) Displacement of the lamina cribrosa in response to acute intraocular pressure elevation in normal individuals of African and European descent. Invest Ophthalmol Vis Sci 57(7):3331–3339
35. Fazio MA, Grytz R, Morris JS, Bruno L, Girkin CA, Downs JC (2014) Human scleral structural stiffness increases more rapidly with age in donors of African descent compared to donors of European descent. Invest Ophthalmol Vis Sci 55(11):7189–7198

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