Clinical science

Clinical characteristics and surgical outcomes of secondary full-thickness macular holes developing after vitrectomy

Beatrice Gallo ,[1] Haseeb Akram,[2] Francesco Maria D'Alterio ,[3] Evgenia Anikina,[4] Haifa Madi,[5] Nikolaos Dervenis ,[3] Colin Goudie,[6] Imran Akram,[7] Mikes Nomikarios,[4] Won Young Moon,[4] Reshma Sonsale,[8] Philip Alexander,[9] Pallavi Tyagi,[8] Teresa Sandinha ,[3,10] David H Steel,[11,12] Michael A Mikhail,[13,14] Aman Chandra[1,15]

► Additional supplemental material is published online only. To view, please visit the journal online (https://doi.org/10.1136/bjo-2025-327250).

For numbered affiliations see end of article.

Correspondence to
Dr Beatrice Gallo;
beatricegallo.bg@gmail.com

Received 24 January 2025
Accepted 1 September 2025

ABSTRACT

Aim To describe the clinical features, anatomical and visual outcomes of secondary full-thickness macular holes (sFTMH) developing after pars plana vitrectomy (PPV).

Methods The medical charts of patients from nine vitreoretinal services across the UK who, between 2009 and 2023, underwent PPV for different indications and subsequently developed sFTMH were retrospectively reviewed. Primary outcomes were clinical features, macular hole closure rate and change in best corrected visual acuity (BCVA). Patients with idiopathic FTMH (iFTMH) who underwent surgical repair in the same period acted as control data for optical coherence tomography (OCT) characteristics.

Results Out of 16 939 PPV undertaken during the study period, 60 eyes of 60 patients (52% females, mean age 61.9 years) developed sFTMH, leading to an incidence of 0.4%. Median follow-up was 24.7 months. The median time from primary PPV to sFTMH diagnosis was 3 (range 0.4–81.4) months. OCT features of sFTMH were compared with 108 cases of iFTMH. Epiretinal membrane (ERM, 24.2%), epiretinal proliferation (ERP, 9.3%) and subretinal fluid cuff (53.7%) were more commonly observed in sFTMH compared with iFTMH (11.1%, p=0.03; 1.9%, p=0.03 and 33.3%, p=0.01, respectively). 10.9% of sFTMH developing after rhegmatogenous retinal detachment (RRD) were associated with giant-retinal tear (GRT) RRD. Single surgery success rate was 93.9%. In 3 (5%) eyes, sFTMH closed spontaneously. BCVA significantly improved from 1.0 logMAR to 0.7 logMAR at final visit.

Conclusions sFTMH presented more commonly with ERM and ERP compared with iFTMH. A high incidence of GRT-related RRD was observed among the RRD cohort. Surgery achieves a closure rate of 93.9% and significant vision improvement.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Secondary full-thickness macular hole (sFTMH) is a rare complication of vitreoretinal surgery with a poorly understood pathogenesis and risk factors that include high myopia, macula affecting rhegmatogenous retinal detachment (RRD) and recurrent RRD.

WHAT THIS STUDY ADDS

⇒ Epiretinal membrane (ERM) is more commonly associated with sFTMH than idiopathic macular holes and with giant retinal tear-related (GRT)-RRD. Surgery has a high success rate of 93.9% and allows significant vision improvement, while spontaneous hole closure occurs in 5% of cases.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study adds important information relative to clinical characteristics and surgical outcomes of sFTMH and will aid surgeons modifying their surgical techniques in order to prevent the onset of sFTMH and improve functional outcomes.

INTRODUCTION

Secondary full thickness macular hole (sFTMH) developing after pars plana vitrectomy (PPV) is a rare postoperative complication first described in two patients undergoing PPV for epiretinal membrane (ERM)[1] and subsequently also reported after surgery for rhegmatogenous retinal detachment (RRD),[2] vitreomacular traction and myopic traction maculopathy.[3] The estimated incidence of sFTMH after RRD repair by all techniques is 0.9–1.9%.[4 5]

Unlike idiopathic FTMH (iFTMH), where a major pathogenetic role is played by tangential and anteroposterior vitreofoveal traction,[6–9] macular holes developing in vitrectomised eyes have an unclear pathogenesis. Two pathogenetic mechanisms have been hypothesised. According to the tractional theory, a full thickness macular defect arises from the tangential traction exerted by ERM or vitreous cortex remnants.[10] The degenerative theory speculates that macular oedema precedes the onset of sFTMH and is supported by the observation that eyes successfully treated for FTMH, which subsequently undergo cataract surgery and develop postoperative macular oedema, have a 7-fold higher risk of macular hole reopening.[11] Other factors

Check for updates

© Author(s) (or their employer(s)) 2025. No commercial re-use. See rights and permissions. Published by BMJ Group.

To cite: Gallo B, Akram H, D'Alterio FM, *et al*. *Br J Ophthalmol* Epub ahead of print: [*please include* Day Month Year]. doi:10.1136/bjo-2025-327250

Br J Ophthalmol: first published as 10.1136/bjo-2025-327250 on 15 September 2025. Downloaded from http://bjo.bmj.com/ on September 15, 2025 by guest. Protected by copyright, including for uses related to text and data mining, AI training, and similar technologies.

observed in association with sFTMH include macula off RRD and recurrent RRD where residual cortical vitreous or incomplete posterior vitreous detachment with subsequent traction may lead to macular hole formation after surgery.[10 12]

The majority of previous studies on sFTMH are represented by small case series including mostly sFTMH occurring after heterogeneous surgical techniques such as PPV, pneumatic retinopexy, scleral buckle and combined PPV-scleral buckle.[12–15] As this heterogeneity underlies different possible causative mechanisms in vitrectomised and non-vitrectomised eyes, the pathogenesis of sFTMH remains poorly elucidated. Here, the purpose of our study is to provide insights into the incidence, demographics, risk factors and surgical outcomes in sFTMH diagnosed exclusively after PPV.

METHODS

Design and data collection

The study was a retrospective cohort study including patients diagnosed with sFTMH after PPV between 2009 and 2023 from participating vitreoretinal centres across the UK using the BEACON (British and Eire Association of Vitreoretinal Surgeons, BEAVRS, case collection initiative) online portal. The research involved retrospective data collection without identifiable private information, and the local Ethics Committee ruled that approval was not required for this study.

Variables analysed

A sFTMH is defined as a full thickness defect in the fovea developing after PPV performed for any indication and confirmed on optical coherence tOptical Coherence Tomography (OCT) (Spectralis, Heidelberg Engineering, Heidelberg, Germany, or Topcon, Japan). We excluded patients who had previously undergone PPV for iFTMH or for RRD with simultaneous FTMH.

The electronic medical records of included patients were reviewed and collected data included: age, gender, ethnicity, laterality, axial length, lens status, ocular co-pathology, indication for primary PPV, PPV details, number of PPVs, best corrected visual acuity (BCVA) before initial PPV and at sFTMH diagnosis, time interval between PPV and sFTMH diagnosis, surgical technique performed for sFTMH repair, BCVA and status of macular hole at final visit. For sFTMH developing after RRD surgery, anatomic features such as type, number and extent of retinal breaks, macular status and presence and grade of proliferative vitreoretinopathy (PVR) were recorded. The surgical procedure and selection of tamponade agent was at the discretion of the operating surgeon. Hyaloid peeling was not performed in any case.

Patients were examined preoperatively, after 3 months from surgery and at final visit before discharge. Each visit included Snellen BCVA, slit lamp biomicroscopy, funduscopy and macular OCT. OCT scans taken at first diagnosis were collected from consecutive eyes of patients with iFTMH who underwent surgery during the same period and served as a control dataset. Optimal balance and precision were achieved through 1:2 matching. The features of macular hole on OCT were independently reviewed by two vitreoretinal specialists (BG and AC) and included minimum linear diameter (MLD) and basal diameter (BD), measured using the 'calliper' function, Diameter Hole Index (DHI, defined as MLD to BD ratio),[16] aspect of the hole defined as 'with cuff' (figure 1) or 'flat' (figure 2), presence of supra-retinal pigmented epithelium (RPE) granular deposits, intraretinal cysts, ERM and epiretinal proliferation (ERP) and aspect of the borders defined as smooth or bumpy.[17] The configuration

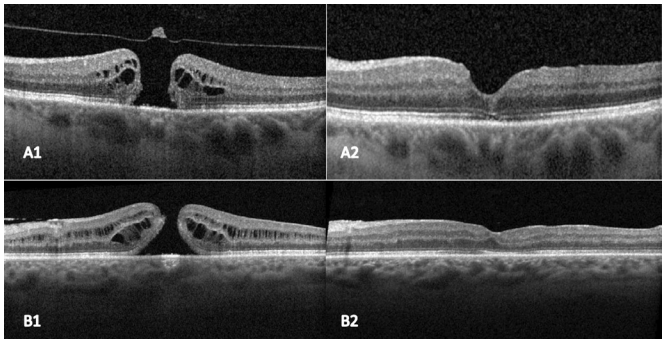


Figure 1 OCT images of idiopathic (A) and secondary (B) full-thickness macular hole before (A1, B1) and after surgery (A2, B2). To be noticed is the 'with cuff' aspect and presence of epiretinal membrane and epiretinal proliferation in secondary full-thickness macular hole.

of macular hole was 'with cuff' if subretinal fluid was present and 'flat' if absent. Supra-RPE granular deposits were multiple hyper-reflective round areas above the RPE at the base of the macular hole. Hole borders were smooth if the surface was even and regular and bumpy if uneven with projections. ERM is defined as a thin hyperreflective line on the inner retinal surface, whereas ERP is defined as thick preretinal material with medium reflectivity.[18] Macular hole closure is defined by restoration of the foveal architecture (type 1 closure pattern).[19]

Outcomes

The primary outcome was to define clinical features, macular hole closure rate and change in BCVA before macular hole surgery and at final visit, termed as ΔBCVA. The secondary outcome was to identify distinctive anatomic features of sFTMH by comparison with iFTMH. The total number of PPV undertaken, with

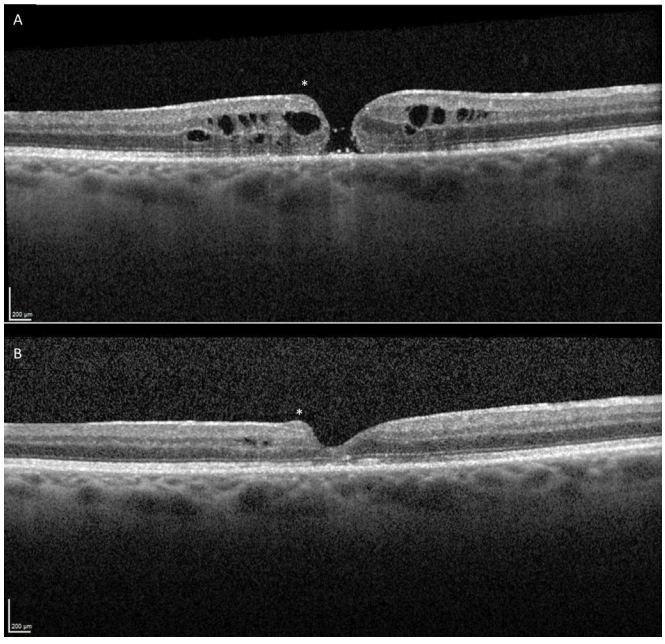


Figure 2 Baseline (A) and follow-up (B) OCT of a patient with secondary full-thickness macular hole that closed spontaneously. To be noticed is the presence of epiretinal proliferation (*), cystic spaces, supra-retinal pigmented epithelium granular deposits and 'flat' configuration at presentation.

Br J Ophthalmol: first published as 10.1136/bjo-2025-327250 on 15 September 2025. Downloaded from http://bjo.bmj.com/ on September 15, 2025 by guest. Protected by copyright, including for uses related to text and data mining, AI training, and similar technologies.

the same exclusion criteria, at each unit during the study period was used to estimate the incidence of sFTMH.

Statistical analysis

Statistical analysis was performed using Microsoft Excel and Stata software (V.14.1 StataCorp, Texas, USA). We created two samples for anatomic analyses, including sFTMH and iFTMH, and matched for macular hole features on OCT described above. Snellen BCVA was converted to the logarithm of the minimal angle of resolution (logMAR). Visual acuities of counting fingers and hand motion were assigned logMAR designations of 1.9 and 2.3, respectively. Comparisons between subgroups were performed by using a two-sided t-test. Outcomes of sFTMH subgroups stratified by baseline BCVA, indication for primary PPV and time of onset were analysed and compared with one-way ANOVA test. P values<0.05 were considered statistically significant.

RESULTS

A total of sixty eyes from sixty patients (31 females, 52%) from nine vitreoretinal centres across the UK with a mean age of 61.9 (range 38–88) years that developed a sFTMH after PPV were included in the study. Sixteen thousand nine hundred thirty-nine PPV, excluding iFTMH, were undertaken at the participating units during the study period, leading to an incidence of sFTMH of 0.4%. Patient demographic and clinical characteristics are reported in table 1.

Indications for primary PPV included: RRD (46 eyes, 76.7%), idiopathic ERM or vitreomacular traction (5 eyes, 8.3%), tractional retinal detachment (3 eyes, 5%), acute submacular haemorrhage (3 eyes, 5%), ocular trauma (2 eyes, 3.3%) and vitreous haemorrhage (1 eye, 1.7%).

The median time between primary PPV and sFTMH diagnosis was 3 (mean 15.3, range 0.4–81.4) months and between sFTMH diagnosis and surgical repair was 1.4 (mean 2.5, range 0.3–19.7) months. Median follow-up after macular hole repair was 5.1 months (median 13.1 months, range 2.3–42.1 months). We did not observe a significant difference in the time of onset of sFTMH and indication for primary PPV (p=0.85).

8 (13.3%) eyes had high myopia defined as axial length ≥26.5 mm. table 2 reports details of primary PPV for RRD cases.

OCT features of sFTMH and iFTMH

The size of sFTMH was small (MLD≤250 microns) in 15 (25%) eyes, medium (MLD 250–400 microns) in 17 (28.3%) eyes and large (MLD≥400 microns) in 28 (46.7%) eyes according to the International Vitreomacular Traction Study Group classification.[9] For sFTMH with available OCT scans (54 eyes), we compared the OCT characteristics with those of iFTMH (108 eyes) diagnosed during the same time period, in order to assess for specific anatomical features (table 3).

sFTMH had more commonly a 'with cuff' configuration compared with iFTMH (p<0.05). Moreover, ERM (24.1%, p=0.03) and ERP (9.3%, p=0.03) were more frequently observed in sFTMH (figure 1). While no significant difference was observed between sFTMH and iFTMH in regards to preoperative MLD, iFTMH had larger preoperative BD (p<0.05) and higher DHI (p=0.02). When comparing the OCT features of sFTMH diagnosed before (26 eyes) and after 90 days (28 eyes) from initial PPV, ERM was observed more commonly in cases diagnosed after 90 days (11.5% vs 35.7%, p<0.05) (online supplemental table 1). The cut-off of 3 months was chosen as it corresponded to the median time of sFTMH development after primary PPV.

Table 1 Demographics and clinical characteristics at presentation of 60 eyes from 60 patients with sFTMH.

Features	N (%)
No. of patients	60
Age at diagnosis (years), median (mean, range)	61.5 (61.9, 38–88)
Gender	
Male	29 (48.3)
Female	31 (51.7)
Ethnicity	
Caucasian	52 (86.7)
African	1 (1.7)
Asian	5 (8.3)
Unknown	2 (3.3)
Laterality	
Right	27 (45)
Left	33 (55)
Time (months) between initial PPV and sFTMH diagnosis, median (mean, range)	3 (15.3, 0.4–81.4)
RRD	3.2 (17.6, 0.4–81.4)
TRD	9 (12.7, 3–26.2)
ERM/VMT	2.9 (11.1, 1.3–42.5)
SMH	0.6 (1.3, 0.5–2.7)
VH	2.8
Trauma	6.6 (6.6, 0.8–12.3)
Time (months) between initial PPV and sFTMH diagnosis, median (mean, range)	3 (15.3, 0.4–81.4)
Time (months) between sFTMH diagnosis and surgery, median (mean, range)	1.4 (2.5, 0.3–19.7)
Follow-up duration (months) median (mean, range)	24.7 (29.7, 0.8–87.3)
Follow-up duration (months) median (mean, range) after PPV for sFTMH	5.1 (13.1, 2.3–42.1)
Primary indication for PPV	
RRD	46 (76.7)
TRD	3 (5)
ERM/VMT	5 (8.3)
SMH	3 (5)
VH	1 (1.7)
Trauma	2 (3.3)
sFTMH size	
small (<250 microns)	15 (25)
medium (250–400 microns)	17 (28.3)
large (>400 microns)	28 (46.7)
Lens status	
Phakic	46 (76.7)
Pseudophakic	12 (20)
Unknown	2 (3.3)
Management strategy (eyes)	
PPV/listed for PPV	49 (81.7)/ 6 (10)
Spontaneous closure	3 (5)
Treatment declined	2 (3.4)
Ocular co-pathology (eyes)	
Amblyopia	2 (3.3)
High myopia	8 (13.3)
Proliferative diabetic retinopathy	2 (3.3)
Diabetic macular oedema	2 (3.3)
Retinal vein occlusion	1 (1.7)
Glaucoma/ocular hypertension	5 (8.3)

VH: vitreous haemorrhage.ERM, epiretinal membrane; PPV, pars plana vitrectomy; RRD, rhegmatogenous retinal detachment; sFTMH, secondary full thickness macular hole; SMH, submacular haemorrhage; TRD, tractional retinal detachment; VMT, vitreomacular traction.

Br J Ophthalmol: first published as 10.1136/bjo-2025-327250 on 15 September 2025. Downloaded from http://bjo.bmj.com/ on September 15, 2025 by guest. Protected by copyright, including for uses related to text and data mining, AI training, and similar technologies.

Table 2 Details of primary surgery for RRD

PPV for RRD	
Features	**n=46 (%)**
Fovea status in RRD eyes	
On	12 (26.1)
Off	30 (65.2)
Unknown	4 (8.7)
Loss of central vision duration (days), median (mean, range) in fovea involving RRD	6 (13.6, 1–100)
No. of clock hours affected by RRD	
<6	19 (41.3)
6–12	23 (50)
Unknown	4 (8.7)
No. of breaks in detached retina, median (mean, range)	2 (2.8, 1–8)
Giant retinal tear	5 (10.9)
PVR grade	
None	34 (73.9)
A	2 (4.3)
B	4 (8.7)
C	3 (6.5)
Unknown	3 (6.5)
PPV gauge	
20 g	1 (2.2)
23 g	21 (45.7)
25 g	21 (45.7)
Unknown	3 (6.5)
Retinopexy	
Endolaser	15 (32.6)
Cryotherapy	22 (47.8)
Both	7 (15.2)
Unknown	2 (4.3)
Method of subretinal fluid drainage	
Through break	34 (73.9)
Retinotomy	7 (15.2)
No drain	2 (4.3)
Unknown	3 (6.5)
Intraoperative use of	
PFCL	9 (19.6)
Vitreous stain	4 (8.7)
Intraocular tamponade	
SF_6	14 (30.4)
C_2F_6	10 (21.7)
C_3F_8	14 (30.4)
Air	–
SO	5 (10.9)
Unknown	3 (6.5)
Lens status	
Phakic	35 (76.1)
Pseudophakic	9 (19.6)
Unknown	2 (4.3)

BCVA, best corrected visual acuity; ERM, epiretinal membrane; ILM, internal limiting membrane; PFCL, perfluorocarbon liquid; PVR, proliferative vitreoretinopathy; RRD, rhegmatogenous retinal detachment; SO, silicone oil.

Surgical technique and anatomical outcomes of sFTMH repair

In 3 (5%) eyes, the sFTMH closed spontaneously and 49 eyes underwent surgery. 6 eyes were listed for surgery by the end of this study, and 2 patients refused surgery. Single surgery success rate was 93.9%. One eye required two vitrectomy surgeries to achieve hole closure. The most commonly adopted technique of macular hole repair was internal limiting membrane (ILM) peeling in 65.3% of eyes, followed by inverted ILM flap, and C_3F_8 was the preferred intraocular tamponade. The time of onset of sFTMH did not have an influence on the choice of the surgical strategy (p=0.74).

The success rate did not differ between the two techniques (93.8% for ILM peeling and 92.3% for ILM flap, p=0.86). In sFTMH treated with inverted ILM flap, the mean MLD was greater than 500 micron and significantly larger than those treated with ILM peeling (mean 510.8 microns vs 362 microns, p<0.05). Postoperative face-down posturing was advised to the vast majority of patients (85.7%) for a median of five (range 1–10) days. Two eyes developed retinal detachment after macular hole repair. No ERM recurrence was observed during the study period. The closure rate after surgery did not differ between sFTMH diagnosed before and after 90 days from primary PPV (91.7% vs 100% p=0.15).

Details of PPV for sFTMH with postoperative anatomical and visual outcomes are reported in online supplemental table 2.

Visual outcomes after sFTMH surgery

Median BCVA at sFTMH diagnosis was 1.0 logMAR (range 0.2–2.3 logMAR), at 3 months from sFTMH surgery was 0.8 logMAR (range 0.1–1.9 logMAR) (p=0.15), and at the final visit was 0.7 logMAR (range 0.1–2.3) (p=0.01) (online supplemental table 2). A statistically significant difference was observed between initial and final BCVA (p<0.05). Median ΔBCVA, defined as the difference between BCVA at sFTMH diagnosis and final visit, was −0.2 (range −1.2 to 1). iFTMH cases had a median preoperative BCVA of 0.8 logMAR (range 0.4–1.9 logMAR) and at final visit of 0.6 logMAR (range 0–1.9 logMAR) (p<0.001). The median ΔBCVA was −0.3 (range −1.4 to 1). Final BCVA did not differ in relation to the time of development of sFTMH (before or after 90 days, median 0.8 vs 0.7 logMAR, p=0.45), and ΔBCVA was not correlated with the indication for primary PPV (p=0.2). We performed a further subanalysis stratifying sFTMH eyes according to baseline BCVA ≥1.0 logMAR, between 1.0 and 0.3 logMAR and ≤0.3 logMAR, and found that eyes presenting with BCVA ≥1.0 logMAR had greater vision improvement after surgical closure of the macular hole (mean ΔBCVA −0.38±0.5, p=0.02).

Characteristics of RRD preceding sFTMH formation

Details of RRD and PPV technique are reported in table 2. RRD was fovea-involving in 30 (65.2%) eyes. PVR was absent in 34 (73.9%) eyes. In 23 (50%) eyes, the detachment extended for more than six clock hours, and there were a median of 2 breaks in detached retina (mean 2.8, range 1–8). In 5 (10.9%) eyes, the retinal detachment was associated with a giant retinal tear (GRT), but no difference was observed in respect to the time of onset of sFTMH in relation to GRT-RRD (p=0.18). We did not observe any significant differences in OCT features of sFTMH according to the fovea status at the time of RRD surgery. However, sFTMH after fovea-sparing RRD developed significantly later than fovea-involving RRD (median 25 vs 2.8 months, p<0.001).

Characteristics of sFTMHs that closed spontaneously

The three (5%) sFTMHs that closed spontaneously were small with mean MLD of 128 (range 116–184) microns, and median time of detection from the primary PPV of 26.2 months (mean

Br J Ophthalmol: first published as 10.1136/bjo-2025-327250 on 15 September 2025. Downloaded from http://bjo.bmj.com/ on September 15, 2025 by guest. Protected by copyright, including for uses related to text and data mining, AI training, and similar technologies.

Table 3 Comparison of OCT features of sFTMH and iFTMH

OCT feature	sFTMH (n=54)	iFTMH (n=108)	P value
MLD (microns), median (mean, range)	387 (426.1, 115–1551)	452.5 (460; 63-979)	0.84
BD (microns), median (mean, range)	925 (1094.4, 250–2817)	968 (956.4; 174–1959)	**0.0056**
DHI, median (mean)	0.42 (0.39)	0.46 (0.48)	**0.021**
Flat configuration (%)	25 (46.3)	72 (66.7)	**0.0126**
'With cuff' configuration (%)	29 (53.7)	36 (33.3)	
Supra-RPE granular deposits (%)	24 (44.4)	54 (50)	0.504
Intraretinal cysts (%)	45 (83.3)	99 (91.7)	0.1116
ERM (%)	13 (24.1)	12 (11.1)	**0.0313**
ERP (%)	5 (9.3)	2 (1.9)	**0.0288**
ERM+ERP (%)	1 (1.9)	0	0.16
Smooth border (%)	42 (77.8)	72 (66.7)	0.1443
Bumpy border (%)	12 (22.2)	36 (33.3)	

Bold values indicate statistical significance.
BD, basal diameter; DHI, Diameter Hole Index; ERM, epiretinal membrane; ERP, epiretinal proliferation; MLD, minimum linear diameter; RPE, retinal pigmented epithelium.

42.4±33.9 months), that is significantly later compared with the entire cohort (median 3 months, mean 15.3±22.9 months). However, the spontaneous closure rate of macular holes diagnosed in the first 3 months from surgery and those diagnosed later did not statistically differ (p=0.09). The median time between diagnosis and spontaneous hole closure was 3 months (mean 2.7 months, range 1–4 months). No topical treatment was administered to these cases. Figure 2 illustrates a case of sFTMH that spontaneously closed. No cases had a prior history of spontaneously closed iFTMH.

DISCUSSION

This study provides the largest cohort to date of sFTMH developing exclusively after PPV. Our sFTMH incidence of 0.4% is lower than the incidence of 1.9% reported by Ishibashi *et al*[5] . However, they studied exclusively sFTMH developing in eyes undergoing PPV for retinal detachment.[5]

The pathophysiology of sFTMH remains poorly understood. Similarly to prior studies, sFTMH developing after fovea-sparing RRD repair developed significantly later than those observed after fovea-involving RRD, and the reason for this difference remains unclear.[12 18] A possible explanation is the stress caused by the foveal detachment or reattachment by altering the intratractional or preretinal tractional forces, which contributes to macular hole formation and may lead to earlier development. We did not detect a significant difference in the time of onset of sFTMH according to the indication for primary PPV.

Interestingly, 10.9% of RRD eyes were affected by GRT-RRD, of which 80% were fovea sparing and 40% were observed in highly myopic eyes. As GRT-RRD represents 1.5% of all RRDs,[20] the incidence observed in our cohort is significantly higher than expected and therefore GRT-RRD might be a risk factor for sFTMH development. It has been suggested that in GRT, vitreoschisis frequently leads to a residual thin layer of hyaloid on the retina, which may be difficult to identify and remove and therefore can result in residual traction.[21 22] An alternative explanation is that, in GRTs, the large area of exposed RPE increases the chances of PVR and ERM formation due to a greater dispersion of RPE cells over and under the retina.[23] A third possible explanation is the use of a greater amount of laser retinopexy in GRT-RRD, which might contribute to ERM onset by stimulating an inflammatory response promoting fibrocellular proliferation. In fact, ERM was significantly more commonly observed after GRT-RRD repair (80%) compared with non-GRT RRD eyes (25.8%) (p<0.05).

We compared the OCT features of iFTMH and sFTMH with the aim of identifying distinctive features and observed that ERM and ERP were more common in sFTMH. Our ERM and ERP incidence is lower than those reported by most prior studies,[10 12 14 15 18 24 25] but given that these included vitrectomised and non-vitrectomised eyes, this difference can be attributed to case heterogeneity. Without performing a PPV, the mechanism of sFTMH may be similar to iFTMH where anteroposterior and tangential traction play a major pathogenetic role. ERM was more frequently detected in sFTMH diagnosed later than 90 days from primary PPV suggesting a time-dependent development of this structure. Both ERP and ERM were more commonly found in association with sFTMH. ERP occurs due to breaks in the foveal ILM associated with posterior vitreous detachment and is caused by proliferation of Müller cells on the inner retina surface, and its role in the pathogenesis of sFTMH is not clear, as unlike ERM, it does not have tractional properties. In particular, we note that no patients had ILM peeling during the first PPV.

The development of ERM is one of the most common causes of visual impairment after successful RRD repair. It is thought to occur as a result of the disruption of the blood-retinal barrier and migration of RPE cells into the vitreous through retinal breaks. The ILM acts as a scaffold for RPE cells' proliferation, and the fact that the ILM was not peeled in the index PPV prior to secondary FTMH formation may thus have contributed to the ERM development. However, ILM had not been peeled prior to iFTMH surgery, so the increased incidence of ERM in sFTMH is of relevance and interest.

In regard to the aspect of the macular hole, the 'with cuff' appearance was more common in the sFTMH group compared with iFTMH that had more frequently 'flat' appearance and greater BD. Traditionally, on OCT, the iFTMH appearance tended to flatten with time. However, in our cohort, the interval between primary PPV and sFTMH diagnosis was significantly longer than the interval between symptom onset and iFTMH diagnosis (median 93 vs 55 days, p<0.001). This paradox may suggest that tangential traction in sFTMH may be greater, thus causing elevation of the hole edges.

In our cohort, the most commonly performed technique of macular hole repair was ILM peeling and C_3F_8 gas tamponade,

Br J Ophthalmol: first published as 10.1136/bjo-2025-327250 on 15 September 2025. Downloaded from http://bjo.bmj.com/ on September 15, 2025 by guest. Protected by copyright, including for uses related to text and data mining, AI training, and similar technologies.

followed by face-down positioning, that achieved a closure rate of 93.9%, irrespective of the time of onset of sFTMH and significant BCVA improvement with positive functional outcomes. Eyes with worse BCVA (≥1.0 logMAR) at the time of sFTMH diagnosis had greater vision gain after surgery, but the time of onset of sFTMH did not affect the final BCVA. The largest previous study on 47 eyes with sFTMH developing after PPV[24] reported a lower closure rate of 70% as ILM peeling was not performed in 43% of the included eyes. Moreover, this study included sFTMH that occurred mainly after PPV for ERM (43%) and only 11% developing after RRD.[24] Another recent study of 29 eyes with sFTMH after PPV for RRD found a closure rate of 88%.[26]

We observed spontaneous closure without medical treatment of sFTMH in 3 (5%) eyes after a median of 3 months (mean 42.4 months), all having a small MLD. Small sFTMH may close spontaneously with no treatment, suggesting that a period of observation of 2–3 months before surgical intervention may be appropriate.[18] Uemura *et al* reported 11 cases of sFTMH after PPV for RRD, with high myopia in half of cases, and observed spontaneous closure in 63% after a mean of 2 months from initial surgery.[18] However, the majority reopened and required definitive surgical repair. A degenerative lamellar hole configuration with ERP and smaller diameter (135 vs 387 microns) was seen in self-closing holes compared with those that did not close spontaneously.[18] To date, the mechanisms of macular hole closure and its relationship with ERP remain poorly elucidated, but a role of Müller cells with a mechanism that resembles the process of foveogenesis has been speculated.[27] In our cohort, we did not observe any case of spontaneously closed macular hole prior to the first PPV, but we acknowledge that some unrecognised spontaneously closed FTMHs may precede the formation of sFTMH.

Limitations of our study include the retrospective nature that limits the quality of data as may introduce selection bias, and the relatively small sample size. The variable final follow-up may limit the conclusions of visual outcomes. Nonetheless, this is the largest multicentric study to date focusing on sFTMH developing exclusively after PPV, thus providing solid and consistent data. Recently, Martins Melo *et al* suggested that bacillary layer detachment plays a central role in the pathogenesis of macular hole observed before and after surgery for fovea sparing RRD.[28] Our study did not focus on this abnormality as OCT was not routinely performed before retinal detachment surgery. All the eyes included in our study were examined preoperatively by experienced vitreoretinal specialists who excluded the presence of a concomitant macular hole. Larger cohort studies are necessary to identify the risk factors associated with sFTMH and allow vitreoretinal surgeons to modify their surgical techniques in order to prevent the onset and improve functional outcomes.

Author affiliations
[1]Vitreoretinal service, Southend University Hospital NHS Foundation Trust, Westcliff-on-Sea, UK
[2]Ophthalmology Department, University Hospitals Coventry and Warwickshire NHS Trust, Coventry, UK
[3]St Paul's Eye Unit, Royal Liverpool University Hospital, Liverpool, England, UK
[4]Vitreoretinal service, Royal Berkshire NHS Foundation Trust, Reading, England, UK
[5]Vitreoretinal service, Sussex Eye Hospital, Brighton and Sussex University Hospitals NHS Trust, Brighton, England, UK
[6]Vitreoretinal service, Princess Alexandra Eye Pavillion, Edinburgh, Scotland, UK
[7]Vitreoretinal service, St Helens and Knowsley Teaching Hospitals NHS Trust, Prescot, UK
[8]Vitreoretinal service, Hillingdon Hospitals NHS Foundation Trust, Uxbridge, England, UK
[9]Vitreoretinal service, Cambridge University Hospitals NHS Foundation Trust, Cambridge, England, UK
[10]Department of Eye and Vision Science, Institute of Ageing and Chronic Disease, University of Liverpool, Liverpool, England, UK
[11]Sunderland Eye Infirmary, Sunderland, UK
[12]Bioscience Institute, Newcastle University, Newcastle upon Tyne, UK
[13]Vitreoretinal service, Kabgayi Eye Unit, Kabgayi Hospital, Muhanga, Southern Province, Rwanda
[14]College of Medicine and Health Science, University of Rwanda, Kigali, Kigali City, Rwanda
[15]Vision & Eye Research Institute, Anglia Ruskin University, Chelmsford, UK

Acknowledgements This manuscript was presented in part at the annual meeting of the British and Eire Association of Vitreoretinal Surgeons (18–19 November 2024), Hull, UK, and at the Floretina meeting, Florence (5–8 December 2024), Florence, Italy.

Contributors Study concept and design: BG and AC. Acquisition, analysis and interpretation of data: BG, HA and AC. Drafting the manuscript and critical revision for important intellectual content: BG and AC. Final approval of the version to be published: BG, HA, FMD, EA, HM, ND, CG, IA, MN, WYM, RS, PA, PT, TS, DHS, MAM and AC . Study guarantors: BG and AC.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article or uploaded as supplementary information.

Supplemental material This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

ORCID iDs
Beatrice Gallo http://orcid.org/0000-0001-6862-6227
Francesco Maria D'Alterio http://orcid.org/0000-0003-4248-4376
Nikolaos Dervenis http://orcid.org/0000-0002-7269-2785
Teresa Sandinha http://orcid.org/0000-0001-5669-7159

REFERENCES

1 Smiddy WE. Atypical presentations of macular holes. *Arch Ophthalmol* 1993;111:626–31.
2 Sheth HG, Bainbridge J. Development of Full-Thickness Macular Hole despite Previous Posterior Vitreous Detachment and Vitrectomy for Retinal Detachment: Two Cases. *Eur J Ophthalmol* 2008;18:1025–7.
3 Wakabayashi T, Shiraki N, Tsuboi K, *et al*. Risk Factors and Outcomes of Postoperative Macular Hole Formation after Vitrectomy for Myopic Traction Maculopathy: SCHISIS Report No. 2. *Ophthalmol Retina* 2023;7:779–87.
4 Benzerroug M, Genevois O, Siahmed K, *et al*. Results of surgery on macular holes that develop after rhegmatogenous retinal detachment. *Br J Ophthalmol* 2008;92:217–9.
5 Ishibashi T, Iwama Y, Nakashima H, *et al*. Foveal Crack Sign: An OCT Sign Preceding Macular Hole After Vitrectomy for Rhegmatogenous Retinal Detachment. *Am J Ophthalmol* 2020;218:192–8.
6 Gass JD. Reappraisal of biomicroscopic classification of stages of development of a macular hole. *Am J Ophthalmol* 1995;119:752–9.
7 Gass JD. Idiopathic senile macular hole. Its early stages and pathogenesis. *Arch Ophthalmol* 1988;106:629–39.
8 Gaudric A, Haouchine B, Massin P, *et al*. Macular hole formation: new data provided by optical coherence tomography. *Arch Ophthalmol* 1999;117:744–51.
9 Duker JS, Kaiser PK, Binder S, *et al*. The International Vitreomacular Traction Study Group Classification of Vitreomacular Adhesion, Traction, and Macular Hole. *Ophthalmology* 2013;120:2611–9.
10 Medina CA, Ortiz AG, Relhan N, *et al*. MACULAR HOLE AFTER PARS PLANA VITRECTOMY FOR RHEGMATOGENOUS RETINAL DETACHMENT. *Retina* 2017;37:1065–72.
11 Bhatnagar P, Kaiser PK, Smith SD, *et al*. Reopening of previously closed macular holes after cataract extraction. *Am J Ophthalmol* 2007;144:252–9.
12 Bomdica PR, Shepherd EA, Chaturvedi V. CHaracteristics, outcomes, and optical coherence tomography features of macular hole after rhegmatogenous retinal detachment repair. *Retina* 2024;44:581–90.
13 Ersoz MG, Hocaoglu M, Sayman Muslubas I, *et al*. Characteristics and management of macular hole developing after rhegmatogenous retinal detachment repair. *Jpn J Ophthalmol* 2021;65:497–505.

Br J Ophthalmol: first published as 10.1136/bjo-2025-327250 on 15 September 2025. Downloaded from http://bjo.bmj.com/ on September 15, 2025 by guest. Protected by copyright, including for uses related to text and data mining, AI training, and similar technologies.

14 Starr MR, Lee C, Arias D, *et al*. Full-thickness macular holes after surgical repair of primary rhegmatogenous retinal detachments: incidence, clinical characteristics, and outcomes. *Graefes Arch Clin Exp Ophthalmol* 2021;259:3305–10.
15 Garcia-Arumi J, Boixadera A, Martinez-Castillo V, *et al*. Macular holes after rhegmatogenous retinal detachment repair: surgical management and functional outcome. *Retina* 2011;31:1777–82.
16 Ruiz-Moreno JM, Staicu C, Piñero DP, *et al*. Optical coherence tomography predictive factors for macular hole surgery outcome. *Br J Ophthalmol* 2008;92:640–4.
17 Govetto A, Bacherini D, Romano MR, *et al*. Full-Thickness Macular Hole: Are Supra-RPE Granular Deposits Remnants of Photoreceptors Outer Segments? Clinical Implications. *Am J Ophthalmol* 2023;245:86–101.
18 Uemura A, Arimura N, Yamakiri K, *et al*. Macular holes following vitrectomy for rhegmatogenous retinal detachment: epiretinal proliferation and spontaneous closure of macular holes. *Graefes Arch Clin Exp Ophthalmol* 2021;259:2235–41.
19 Kang SW, Ahn K, Ham D-I. Types of macular hole closure and their clinical implications. *Br J Ophthalmol* 2003;87:1015–9.
20 Mitry D, Singh J, Yorston D, *et al*. The predisposing pathology and clinical characteristics in the Scottish retinal detachment study. *Ophthalmology* 2011;118:1429–34.
21 Genovesi-Ebert F, Rizzo S, Chiellini S, *et al*. Echographic study of the vitreoretinal interface in giant retinal tears. *Ophthalmologica* 1998;212 Suppl 1:89–90.
22 Schepens CL, Freeman HM. Current management of giant retinal breaks. *Trans Am Acad Ophthalmol Otolaryngol* 1967;71:474–87.
23 Leaver PK, Lean JS. Management of giant retinal tears using vitrectomy and silicone oil/fluid exchange. A preliminary report. *Trans Ophthalmol Soc U K (1962)* 1981;101:189–91.
24 Kumagai K, Ogino N, Furukawa M, *et al*. Surgical Outcomes for Patients who Develop Macular Holes After Pars Plana Vitrectomy. *Am J Ophthalmol* 2008;145:1077–80.
25 Khurana RN, Wieland MR. Topical Steroids for Recurrent Macular Hole after Pars Plana Vitrectomy. *Ophthalmol Retina* 2018;2:636–7.
26 Schöneberger V, Jonas RA, Menghesha L, *et al*. SECONDARY FULL THICKNESS MACULAR HOLES FOLLOWING COMPLETE VITRECTOMY FOR RHEGMATOGENOUS RETINAL DETACHMENT: Rare Occurrence With Good Closure Rate. *Retina* 2025;45:1089–96.
27 Bringmann A, Duncker T, Jochmann C, *et al*. Spontaneous closure of small full-thickness macular holes: Presumed role of Müller cells. *Acta Ophthalmol* 2020;98:e447–56.
28 Martins Melo I, Jhaveri A, Bansal A, *et al*. Pathophysiology of Secondary Macular Hole in Rhegmatogenous Retinal Detachment. *Invest Ophthalmol Vis Sci* 2023;64:12.

Br J Ophthalmol: first published as 10.1136/bjo-2025-327250 on 15 September 2025. Downloaded from http://bjo.bmj.com/ on September 15, 2025 by guest. Protected by copyright, including for uses related to text and data mining, AI training, and similar technologies.