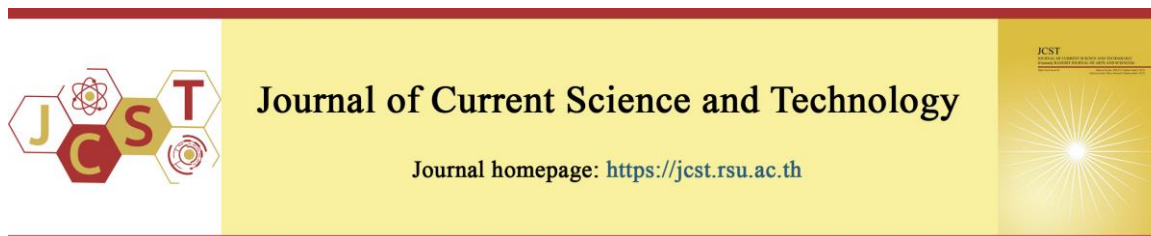


Cite this article: Nguyen, D. A., Nguyen, H. B., Dang, T. D., Ho, X. H., & Nguyen, T. T. (2026). Clinical and optical coherence tomography characteristics of large primary macular holes. *Journal of Current Science and Technology*, 16(4), Article 223. <https://doi.org/10.59796/jcst.V16N4.2026.223>



Clinical and Optical Coherence Tomography Characteristics of Large Primary Macular Holes

Duc Anh Nguyen^{1,2},
Huy Binh Nguyen¹,
Tran Dat Dang^{2,*},
Xuan Hai Ho²,
Thu Trang Nguyen²,

¹Hanoi Medical University, Hanoi, Vietnam
²Vietnam National Eye Hospital, Hanoi, Vietnam

*Corresponding author; E-mail: dangtrandat.vnio@gmail.com

Received 21 May 2026; Revised 27 June 2026; Accepted 3 July 2026; Published 15 September 2026

Abstract

Large primary full-thickness macular holes are associated with visual impairment and complex optical coherence tomography (OCT) abnormalities. This single-center cross-sectional study described pretreatment clinical and OCT characteristics of large primary macular holes and explored associations with symptom duration and visual acuity. Forty eyes from 40 surgical candidates with primary macular holes and a minimum linear diameter (MLD) > 400 μm were analyzed at Vietnam National Eye Hospital, Hanoi, Vietnam, from March to December 2025. Clinical variables included age, sex, symptom duration, and best-corrected visual acuity (BCVA). OCT variables included vitreomacular status, fluid cuff, intraretinal cyst severity, MLD, base diameter, hole height, external limiting membrane (ELM) and ellipsoid zone (EZ) defect lengths, macular thickness parameters, and macular hole indices. Mean age was 63.7 ± 8.4 years, and women accounted for 57.5% of patients. Mean BCVA was 1.47 ± 0.44 logMAR. Mean MLD, base diameter, and hole height were 594.3 ± 155.8 μm , 1234.9 ± 456.3 μm , and 480.3 ± 110.4 μm , respectively. Complete posterior vitreous detachment, fluid cuff, and intraretinal cysts of any severity were observed in 77.5%, 57.5%, and 85.0% of eyes, respectively. Longer symptom duration was associated with larger MLD and lower HFF and THI. Poorer BCVA was associated with larger MLD and lower MHI and THI. Outer retinal defect lengths correlated with hole size, and fluid cuff was associated with wider structural disruption. Comprehensive pretreatment OCT assessment helps characterize structural severity in large primary macular holes. These associations are exploratory and should be validated prospectively.

Keywords: ellipsoid zone, external limiting membrane, large primary macular hole, macular hole indices, optical coherence tomography, visual acuity, vitreomacular interface

1. Introduction

A primary full-thickness macular hole is a vision-threatening vitreoretinal interface disorder that reduces central vision and daily visual function, particularly in older adults (Jenchitr et al., 2024). The condition has historically been explained by

vitreofoveal traction and foveal dehiscence, and optical coherence tomography (OCT) has since shifted classification from biomicroscopic staging toward measurable anatomic descriptors (Duker et al., 2013; Gass, 1988; La Cour & Friis, 2002; The Royal College of Ophthalmologists, 2025). Its epidemiology

and morphology vary across populations, but older age and female sex are repeatedly reported as common demographic features (Forsaa et al., 2018; Sinawat et al., 2021).

Large macular holes are conventionally defined by a minimum linear diameter (MLD) $> 400\ \mu\text{m}$, a cutoff retained in OCT-based classification and contemporary clinical guidance (Duker et al., 2013; The Royal College of Ophthalmologists, 2025). This category is clinically heterogeneous: the Manchester Large Macular Hole Study suggested high closure rates for standard surgery up to approximately $650\ \mu\text{m}$, while recent consensus statements still identify larger size and longer duration as adverse prognostic features (Ch'ng et al., 2018; Radke et al., 2025). Thus, the large-hole label alone may be less informative than a broader pretreatment OCT phenotype that includes hole geometry, outer retinal integrity, and perifoveal tissue changes.

Symptom duration is also clinically and biologically relevant because prolonged persistence may allow tractional and degenerative changes to enlarge the aperture and flatten the hole configuration. Although no universal chronicity threshold exists, a 12-month boundary has been used pragmatically in clinical interpretation to distinguish longer-standing holes in which structural flattening and less favorable surgical results may be more likely (Murphy et al., 2023; Yun et al., 2012).

However, pretreatment datasets focused specifically on large primary macular holes remain limited. Many studies emphasize postoperative closure or visual recovery, whereas existing pretreatment OCT reports often include heterogeneous hole sizes or evaluate isolated OCT parameters. The present baseline analysis is distinct because it focuses on a surgical-candidate cohort restricted to large primary macular holes and integrates hole geometry, outer retinal defects, fluid cuff, intraretinal cyst severity, macular thickness parameters, and vitreomacular status within a single pretreatment phenotype.

To address this gap, the present study describes the clinical and OCT profile of large primary macular holes before treatment and examines how visual acuity, symptom duration, outer retinal defects, fluid cuff, and intraretinal cysts relate to hole morphology.

2. Objectives

The objective of this study was to describe pretreatment clinical and OCT characteristics of large primary macular holes and to determine how symptom duration, visual acuity, vitreomacular status,

fluid cuff, intraretinal cysts, and outer retinal defect length relate to hole morphology before treatment.

3. Materials and Methods

3.1 Study Design and Setting

This was a cross-sectional observational study conducted at Vietnam National Eye Hospital, Hanoi, Vietnam, from March 2025 to December 2025. The study was designed to characterize pretreatment clinical and OCT findings in eyes with large primary macular holes. In this manuscript, primary full-thickness macular hole denotes an idiopathic full-thickness macular hole without secondary causes; the term primary is used throughout for consistency.

3.2 Participants and Eligibility

The present baseline analysis was derived from the surgical-candidate cohort of the broader approved parent protocol on inverted internal limiting membrane flap surgery. During the study period, 40 consecutive surgical candidates who fulfilled the inclusion criteria were included in this analysis. No patient contributed both eyes to the dataset, and all included eyes had gradable baseline OCT images. Eyes were excluded if they had secondary macular holes, other vitreoretinal diseases, glaucoma, optic neuropathy, amblyopia, or media opacity severe enough to interfere with clinical examination or OCT image acquisition.

3.3 Clinical Assessment and OCT Measurements

All patients underwent standardized history-taking, comprehensive ophthalmic examination, and OCT imaging before treatment. Clinical variables included age, sex, symptom duration, and pretreatment best-corrected visual acuity (BCVA), which was converted to logarithm of the minimum angle of resolution (logMAR) units for analysis.

OCT imaging was performed using a spectral-domain OCT system (Cirrus HD-OCT 5000; Carl Zeiss Meditec, Dublin, CA, USA) with the Macular Cube 512×128 scan protocol centered on the fovea. Only scans with adequate visualization of the macular hole margins and retinal layers were used for analysis. Scans with poor fixation, motion artifacts, marked segmentation errors, or media opacity that prevented reliable measurement were excluded.

Horizontal and vertical B-scans passing through the center of the macular hole were reviewed. The scan showing the clearest and widest representation of the macular hole was selected for quantitative measurement. Central subfield thickness

(CST) and cube average thickness (CAT) were recorded from the automated macular thickness output after checking segmentation quality.

OCT variables included vitreomacular status, the presence of a fluid cuff, intraretinal cyst severity, minimum linear diameter (MLD), base diameter (BD), hole height (HH), external limiting membrane (ELM) defect length, ellipsoid zone (EZ) defect length, CST, CAT, and derived macular hole indices. MLD was defined as the shortest distance between the opposing edges of the macular hole at the narrowest aperture. BD was measured as the distance between the two edges of the hole at its base, near the retinal pigment epithelium. HH was measured as the vertical distance from the base of the hole to the highest point of the elevated hole margin. ELM and EZ defect lengths were measured as the horizontal distances between the two visible ends of the disrupted ELM and EZ bands, respectively. A representative OCT B-scan illustrating these measurement landmarks is shown in Figure 1.

Vitreomacular status was classified according to the International Vitreomacular Traction Study (IVTS) framework. The posterior hyaloid was first assessed for complete separation, vitreomacular adhesion without traction, or vitreomacular traction.

Vitreomacular adhesion without traction was not observed in this cohort. Eyes with persistent perifoveal posterior hyaloid attachment accompanied by foveal deformation or tractional configuration were categorized as vitreomacular traction, whereas eyes with complete separation of the posterior hyaloid from the macula were categorized as complete posterior vitreous detachment. Therefore, the dichotomous analysis compared only the two observed categories: complete posterior vitreous detachment and vitreomacular traction.

Derived indices were calculated as follows: macular hole index (MHI) = HH/BD , tractional hole index (THI) = HH/MLD , hole form factor (HFF) = sum of the nasal and temporal arm lengths/ BD , and diameter hole index (DHI) = MLD/BD . Intraretinal cysts were defined as hyporeflective cystoid spaces within the retinal tissue surrounding the macular hole. Cyst severity was classified according to the largest cyst diameter on the OCT B-scan showing the largest cystic space: absent if no intraretinal cyst was identified, mild if the largest cyst diameter was $< 200 \mu\text{m}$, and severe if the largest cyst diameter was $\geq 200 \mu\text{m}$. The largest cyst diameter was measured manually with the same built-in OCT caliper tool used for the other OCT parameters.

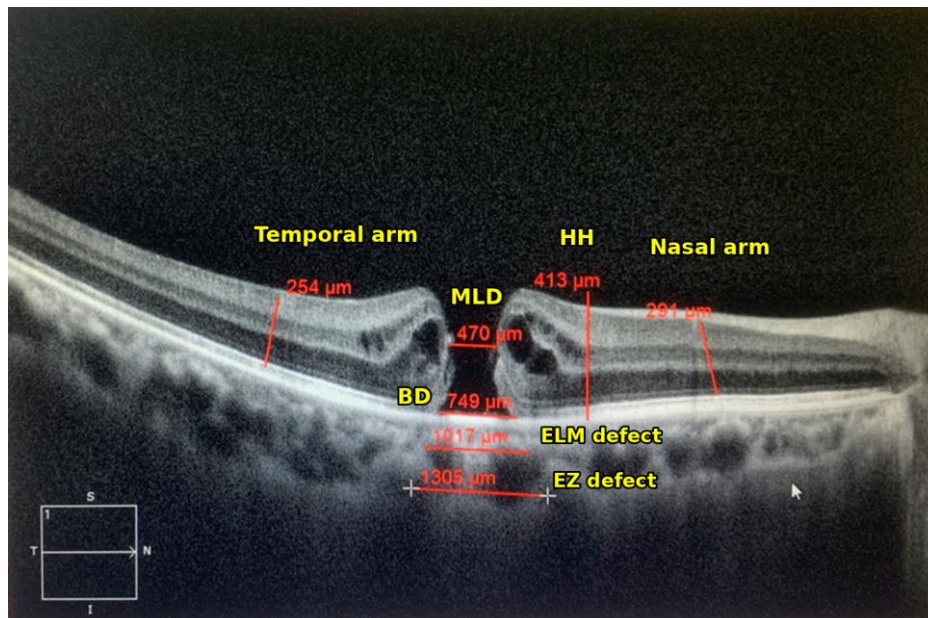


Figure 1 Representative optical coherence tomography B-scan showing measurement landmarks in a large primary macular hole. Labels and red calipers indicate the minimum linear diameter (MLD, $470 \mu\text{m}$), base diameter (BD, $749 \mu\text{m}$), hole height (HH, $413 \mu\text{m}$), temporal arm length ($254 \mu\text{m}$), nasal arm length ($291 \mu\text{m}$), external limiting membrane (ELM) defect length ($1017 \mu\text{m}$), and ellipsoid zone (EZ) defect length ($1305 \mu\text{m}$).

Origin declaration: Image obtained by the authors during this study

All OCT measurements were performed manually by the principal author using the built-in OCT caliper tool. Each parameter was measured three times, and the mean of the three measurements was used for statistical analysis. The OCT grader was not formally masked to clinical data, including BCVA and symptom duration, at the time of OCT measurement.

3.4 Statistical Analysis

All statistical analyses were exploratory and hypothesis-generating. Because multiple pairwise correlations and group comparisons were performed, no correction for multiplicity was applied; p values, especially borderline values, were interpreted descriptively and cautiously. Categorical variables were summarized as frequencies and percentages. Continuous variables were presented as mean $\pm$ standard deviation or median (interquartile range), depending on distribution. Distributional patterns were assessed by visual inspection and the Shapiro-Wilk test. Because the main comparative analyses involved small groups and non-normal distributions, nonparametric tests were used. The Mann-Whitney U test was used for two-group comparisons, and the Kruskal-Wallis test was used for comparisons across intraretinal cyst severity groups. Symptom duration was analyzed both as a dichotomous variable using a 12-month threshold, selected before the comparative analyses as a clinically pragmatic cutoff for longer-standing disease, and as a continuous variable in exploratory Spearman correlations with MLD, HFF, and THI. The threshold was not derived from a post-hoc median split of this cohort. Spearman correlation analysis was also used to evaluate associations between BCVA and OCT parameters and selected OCT-OCT relationships. A two-sided p value <0.05 was used as the threshold for statistical significance in these exploratory analyses.

3.5 Ethical Considerations

This cross-sectional analysis of pretreatment clinical and optical coherence tomography data was performed within a broader approved research protocol on surgical outcomes of the inverted internal limiting membrane flap technique for primary full-

thickness macular holes. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Hanoi Medical University Institutional Ethical Review Board (HMU IRB), Hanoi Medical University (Approval No. 1676/GCN-HMUIRB; approved on February 25, 2025). Data collection under the approved protocol was conducted at the Vietnam National Eye Hospital (Vietnam National Institute of Ophthalmology) and involved patients with primary full-thickness macular holes. The approved documents included the research proposal and informed consent form. All participants received an explanation of the study objectives and procedures, and written informed consent was obtained before enrollment. Patient confidentiality was maintained throughout data collection, analysis, and reporting.

4. Results

4.1 Baseline Characteristics

This study analyzed 40 eyes from 40 patients with primary full-thickness macular holes and a minimum linear diameter $>400\ \mu\text{m}$. The main clinical and OCT characteristics are summarized in Table 1.

The cohort comprised 40 eyes from 40 surgical candidates. Patients were predominantly older adults (mean age, 63.7 ± 8.4 years) and women (57.5%). Most eyes had symptom duration ≤ 12 months (67.5%), and the mean pretreatment BCVA was 1.47 ± 0.44 logMAR. The cohort represented a large-hole phenotype, with a mean MLD of $594.3 \pm 155.8\ \mu\text{m}$ and frequent complete posterior vitreous detachment, fluid cuff, and intraretinal cysts of any severity (77.5%, 57.5%, and 85.0%, respectively) (Table 1).

4.2 Comparisons According to Symptom Duration

Compared with eyes with symptom duration ≤ 12 months, eyes with symptom duration > 12 months had a larger median MLD (629.0 vs. 498.0 μm , $p = 0.019$) and lower HFF (0.64 vs. 0.74, $p = 0.025$) and THI (0.70 vs. 0.92, $p = 0.009$) (Figure 2). When symptom duration was analyzed as a continuous variable, it correlated positively with MLD ($\rho = 0.481$, $p = 0.002$) and negatively with HFF ($\rho = -0.465$, $p = 0.002$) and THI ($\rho = -0.435$, $p = 0.005$).

Table 1 Baseline clinical and OCT characteristics of the study sample

Variable	Result
Age (years)	63.7 ± 8.4
Sex	Male 17/40 (42.5%) Female 23/40 (57.5%)
Symptom duration	≤12 months 27/40 (67.5%) >12 months 13/40 (32.5%)
BCVA	1.47 ± 0.44 logMAR
Vitreomacular status	Complete posterior vitreous detachment 31/40 (77.5%) Vitreomacular traction 9/40 (22.5%)
Fluid cuff	No 17/40 (42.5%) Yes 23/40 (57.5%)
Intraretinal cysts	None 6/40 (15.0%) Mild 9/40 (22.5%) Severe 25/40 (62.5%)
OCT parameters	MLD 594.3 ± 155.8 μm BD 1234.9 ± 456.3 μm HH 480.3 ± 110.4 μm
Outer retinal defects	ELM defect 2019.6 ± 1059.2 μm EZ defect 1936.3 ± 796.1 μm
OCT indices	MHI 0.43 ± 0.16 HFF 0.72 ± 0.18 THI 0.87 ± 0.30 DHI 0.52 ± 0.15
Macular thickness	CST 308.4 ± 128.6 μm CAT 300.1 ± 36.4 μm

Note: Quantitative data are presented as mean ± standard deviation unless otherwise indicated

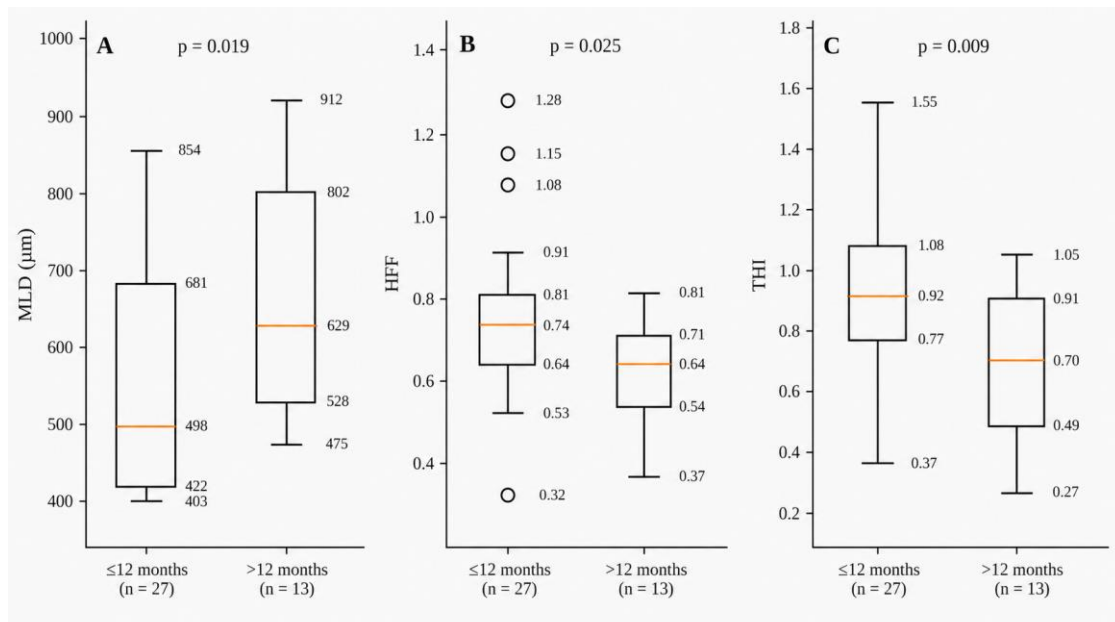


Figure 2 Box-and-whisker plots comparing MLD, HFF, and THI between symptom-duration groups. (A) Minimum linear diameter (MLD), (B) hole form factor (HFF), and (C) tractional hole index (THI) in eyes with symptom duration ≤ 12 months and > 12 months.

Origin declaration: Created by the authors based on the data obtained in this study

Table 2 Spearman correlations among BCVA and selected OCT parameters

Correlation	Spearman's rho	<i>p</i>
BCVA - MLD	0.526	< 0.001
BCVA - MHI	-0.357	0.024
BCVA - THI	-0.503	< 0.001
MLD - ELM defect	0.547	< 0.001
MLD - EZ defect	0.403	0.010
ELM defect - EZ defect	0.810	< 0.001
BCVA - ELM defect	0.243	0.130
BCVA - EZ defect	0.210	0.193

Table 3 Comparison of selected OCT parameters by vitreomacular status

Variable	Vitreomacular traction	Complete posterior vitreous detachment	<i>p</i>
MLD	478.0 (414.0 – 525.0)	576.0 (491.0 – 758.0)	0.024
ELM defect length	1249.0 (1028.0 – 2095.5)	1920.0 (1400.0 – 2812.0)	0.043
HFF	0.78 (0.70 – 1.12)	0.70 (0.60 – 0.75)	0.012
MHI	0.45 (0.38 – 0.66)	0.38 (0.34 – 0.49)	0.121
THI	1.00 (0.83 – 1.14)	0.85 (0.58 – 0.99)	0.075

Note: Values are median (interquartile range)

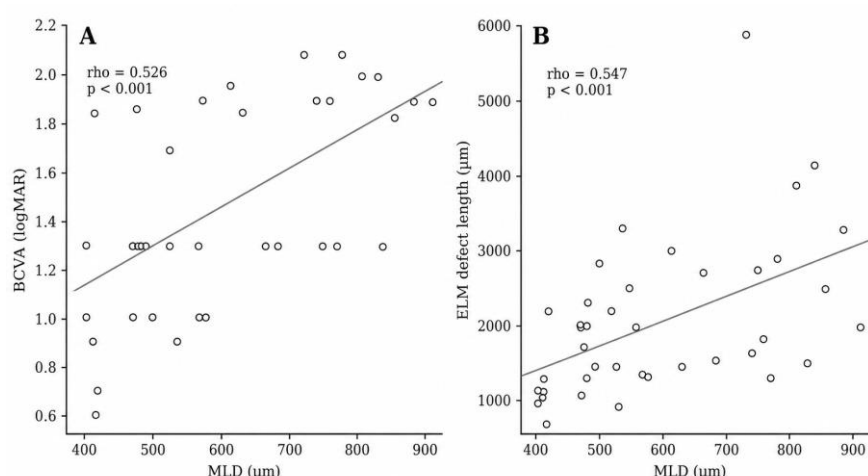


Figure 3 Scatter plots showing correlations of MLD with BCVA and ELM defect length: (A) Correlation between minimum linear diameter (MLD) and best-corrected visual acuity (BCVA). (B) Correlation between MLD and external limiting membrane (ELM) defect length.

Origin declaration: Created by the authors based on the data obtained in this study

4.3 Correlations between BCVA and OCT Parameters

BCVA in logMAR units was positively correlated with MLD ($\rho = 0.526$, $p < 0.001$) and negatively correlated with MHI ($\rho = -0.357$, $p = 0.024$) and THI ($\rho = -0.503$, $p < 0.001$). MLD was correlated with ELM defect length ($\rho = 0.547$, $p < 0.001$) and EZ defect length ($\rho = 0.403$, $p = 0.010$), whereas ELM defect length was strongly correlated with EZ defect length ($\rho = 0.810$, $p < 0.001$). BCVA was not significantly correlated with ELM or EZ defect length (Table 2; Figure 3).

4.4 OCT Parameters According to Vitreomacular Status

Eyes with vitreomacular traction had smaller MLD than eyes with complete posterior vitreous detachment (478.0 vs. 576.0 μm , $p = 0.024$), shorter ELM defect length (1249.0 vs. 1920.0 μm , $p = 0.043$), and higher HFF (0.78 vs. 0.70, $p = 0.012$). Differences in MHI and THI did not reach statistical significance (Table 3).

Table 4 Comparison of selected OCT parameters by fluid cuff status

Variable	Yes	No	<i>p</i>
BD	1420.0 (1075.0 - 1767.0)	988.0 (706.5 - 1171.5)	< 0.001
HH	540.0 (474.0 - 605.0)	413.0 (367.5 - 449.5)	< 0.001
EZ defect length	2073.0 (1623.0 - 2397.0)	1577.0 (1337.0 - 1655.5)	0.006
DHI	0.42 (0.36 - 0.52)	0.63 (0.49 - 0.72)	< 0.001

Note: Values are median (interquartile range)

Table 5 Comparison of selected OCT parameters by intraretinal cyst severity

Variable	None	Mild	Severe	<i>p</i>
HH	332.5 (259.5 - 391.5)	434.0 (383.0 - 531.5)	517.0 (444.5 - 594.5)	< 0.001
MHI	0.24 (0.17 - 0.39)	0.38 (0.34 - 0.53)	0.45 (0.38 - 0.55)	0.008
THI	0.43 (0.35 - 0.73)	0.73 (0.56 - 0.97)	0.93 (0.82 - 1.07)	0.001
CST	127.0 (90.0 - 249.8)	277.0 (190.0 - 366.5)	372.0 (292.0 - 460.0)	0.001
CAT	265.5 (232.3 - 309.5)	291.0 (265.0 - 316.5)	301.0 (292.5 - 317.0)	0.044
BCVA	1.90 (1.20 - 2.10)	1.30 (1.30 - 1.88)	1.30 (1.00 - 1.90)	0.368
MLD	739.0 (601.5 - 803.5)	629.0 (447.5 - 791.5)	522.0 (471.5 - 595.0)	0.211
BD	1128.0 (948.5 - 2290.0)	1161.0 (801.0 - 1421.0)	1142.0 (918.0 - 1459.5)	0.901

Note: Values are median (interquartile range). Intraretinal cyst severity was classified by the largest cyst diameter on OCT: mild < 200 μ m and severe $\geq$ 200 μ m

4.5 OCT Parameters According to Fluid Cuff Status

Eyes with a fluid cuff had larger BD (1420.0 vs. 988.0 μ m, $p < 0.001$), larger HH (540.0 vs. 413.0 μ m, $p < 0.001$), greater EZ defect length (2073.0 vs. 1577.0 μ m, $p = 0.006$), and lower DHI (0.42 vs. 0.63, $p < 0.001$) than eyes without a fluid cuff (Table 4).

4.6 OCT Parameters According to Intraretinal Cyst Severity

Using the prespecified 200 μ m cyst-diameter cutoff, intraretinal cyst severity was associated with HH ($p < 0.001$), MHI ($p = 0.008$), THI ($p = 0.001$), CST ($p = 0.001$), and CAT ($p = 0.044$). BCVA, MLD, and BD did not differ significantly across cyst severity groups (Table 5).

5. Discussion

Large primary macular holes in this single-center Vietnamese surgical-candidate cohort showed a coherent pretreatment OCT phenotype in which longer symptom duration, poorer visual acuity, wider tissue loss, outer retinal disruption, fluid cuff, and intraretinal cystic changes were interrelated. The novel contribution of this study is that it does not simply repeat general macular-hole staging or postoperative prognostic analysis. Instead, it integrates multiple pretreatment OCT dimensions: hole geometry, outer retinal defects, fluid cuff, intraretinal cyst severity, macular thickness output, and vitreomacular status, in a cohort restricted to large primary holes, a subgroup in which surgical decision-

making is clinically important. Given the exploratory cross-sectional design, these associations should be interpreted as baseline structural relationships rather than evidence of temporal progression or independent prognostic effects.

The demographic profile of this series was consistent with the usual pattern of primary macular hole, which occurs more frequently in older adults and women (Forsaa et al., 2018). The mean MLD of nearly 600 μ m confirms that the cohort represented a genuinely large-hole phenotype rather than a mixed sample of small, medium, and large holes. This distinction is important because large holes may require different surgical planning and have different prognostic expectations (Rezende et al., 2023; Sinawat et al., 2021).

Longer symptom duration was associated with larger median MLD and lower HFF and THI, and the continuous duration analyses showed the same directional pattern. This finding is anatomically plausible because chronic tractional and degenerative changes can enlarge the aperture and flatten the hole configuration. It is also consistent with evidence that symptom duration adversely affects surgical closure and postoperative vision, although the present cross-sectional design cannot determine progression or treatment response (Murphy et al., 2023; Yun et al., 2012). This interpretation should also account for potential recall error because symptom duration was self-reported.

Worse pretreatment BCVA, expressed as higher logMAR values, was associated with larger MLD and

lower MHI and THI. Previous OCT-based studies have shown that size and configuration indices, including MHI and THI, help summarize tissue geometry and are associated with visual or anatomical outcomes after surgery (Kusuhara et al., 2004; Ruiz-Moreno et al., 2008; Venkatesh et al., 2019). In the present pretreatment dataset, the same indices appear to capture baseline structural severity rather than postoperative prognosis.

Outer retinal damage was closely related to hole size. MLD correlated with both ELM and EZ defect lengths, and ELM defect length correlated strongly with EZ defect length. These findings support the concept that large-hole morphology includes not only inner retinal dehiscence but also photoreceptor-interface disruption, a feature repeatedly linked to visual recovery after macular hole repair (Houly et al., 2017; Oh et al., 2010; Yang et al., 2021).

Vitreomacular interface status contributed additional structural information. Eyes with persistent vitreomacular traction had smaller MLD, shorter ELM defect length, and higher HFF than eyes with complete posterior vitreous detachment. This pattern is compatible with the IVTS framework, in which full-thickness macular holes are classified by both size and the presence or absence of vitreomacular traction, and with clinical guidance recommending that vitreous status be documented on OCT (Duker et al., 2013; The Royal College of Ophthalmologists, 2025).

Fluid cuff and intraretinal cysts described the perifoveal tissue response around the hole. Fluid cuff was associated with larger BD and HH, greater EZ defect length, and lower DHI, suggesting a more extensive configuration at the hole base and outer retina. Increasing intraretinal cyst severity was linked to HH, MHI, THI, CST, and CAT but not to BCVA, MLD, or BD, supporting the view that cystic morphology reflects retinal deformation rather than serving as a direct surrogate for visual loss (Goto et al., 2020; Ozturk et al., 2022). Because cyst severity was categorized using a 200 μm diameter threshold, this variable should be interpreted as a semiquantitative OCT descriptor rather than a continuous measure of cystic change.

Taken together, these findings support a compact pretreatment OCT profile for large primary macular holes: MLD to define size, MHI, THI, HFF, and DHI to describe geometry, ELM and EZ defect lengths to quantify outer retinal injury, and fluid cuff, cystic change, and vitreomacular status to describe the

local tissue environment. This profile is clinically useful because the conventional $> 400 \mu\text{m}$ category may contain anatomically heterogeneous lesions, and contemporary literature increasingly supports more granular stratification of large holes (Ch'ng et al., 2018; Radke et al., 2025; Rezende et al., 2023).

6. Research Limitations and Benefits

Several limitations should be considered. The cross-sectional design did not allow evaluation of temporal change, spontaneous progression, or postoperative outcomes, and the associations reported here should not be interpreted as causal or prognostic. The sample size was modest, and the study was conducted at a single tertiary eye hospital, which may limit generalizability and increase referral-selection bias. Because the cohort was derived from surgical candidates in a parent inverted internal limiting membrane flap protocol, it should not be interpreted as an unselected large-macular-hole population. A separate screening log for all patients assessed during the study period but not entered into the parent surgical protocol was not available. Symptom duration was self-reported and may be affected by recall bias. OCT measurements were performed by a single grader, although each parameter was measured three times and averaged; intergrader reproducibility was not assessed. Because the OCT grader was not formally masked to BCVA and symptom duration, measurement expectation bias cannot be completely excluded. CST and CAT were device-derived measurements from a Cirrus HD-OCT protocol and may not be directly comparable with outputs from other OCT platforms. Finally, because this was an exploratory baseline analysis, no multivariable adjustment or correction for multiple testing was applied; therefore, the findings should be interpreted as hypothesis-generating, particularly for borderline p values.

The main benefit of this study is its focused characterization of large primary macular holes using a detailed pretreatment OCT dataset. By linking symptom duration, visual acuity, vitreomacular status, fluid cuff, intraretinal cyst severity, and outer retinal defect length, the study provides a structured baseline description that may support clinical phenotyping and guide the design of prospective studies with postoperative follow-up.

7. Conclusion

Large primary macular holes showed marked pretreatment OCT abnormalities. Symptom duration

was associated with wider and less favorable hole geometry, whereas pretreatment visual acuity was related to both MLD and geometric indices. Outer retinal damage, fluid cuff, and intraretinal cysts contributed additional information about structural severity. Within the limitations of an exploratory cross-sectional design, comprehensive pretreatment OCT assessment is useful for describing the phenotype of large primary macular holes before treatment.

8. Acknowledgements

The authors thank the staff of Vietnam National Eye Hospital and all study participants for their cooperation.

Funding: This research received no external funding.

Conflicts of interest: The authors declare no conflicts of interest.

9. Abbreviations

Abbreviation	Full Term
BCVA	Best-corrected visual acuity
BD	Base diameter
CAT	Cube average thickness
CST	Central subfield thickness
DHI	Diameter hole index
ELM	External limiting membrane
EZ	Ellipsoid zone
HFF	Hole form factor
HH	Hole height
IVTS	International Vitreomacular Traction Study
LogMAR	Logarithm of the minimum angle of resolution
MHI	Macular hole index
MLD	Minimum linear diameter
OCT	Optical coherence tomography
THI	Tractional hole index

10. CRediT Statement

Duc Anh Nguyen: Conceptualization, investigation, data curation, formal analysis, visualization, and writing – original draft.

Huy Binh Nguyen: Conceptualization, methodology, supervision, and writing – review and editing.

Tran Dat Dang: Methodology, supervision, resources, and writing – review and editing.

Xuan Hai Ho: Investigation, data collection, resources, and writing – review and editing.

Thu Trang Nguyen: Investigation, data collection, data curation, and writing – review and editing.

11. References

- Ch'ng, S. W., Patton, N., Ahmed, M., Ivanova, T., Baumann, C., Charles, S., & Jalil, A. (2018). The Manchester large macular hole study: Is it time to reclassify large macular holes?. *American Journal of Ophthalmology*, 195, 36-42. <https://doi.org/10.1016/j.ajo.2018.07.027>
- Duker, J. S., Kaiser, P. K., Binder, S., de Smet, M. D., Gaudric, A., Reichel, E., ... & Stalmans, P. (2013). The International Vitreomacular Traction Study Group classification of vitreomacular adhesion, traction, and macular hole. *Ophthalmology*, 120(12), 2611-2619. <https://doi.org/10.1016/j.ophtha.2013.07.042>
- Forsaa, V. A., Lindtjørn, B., Kvaløy, J. T., Frøystein, T., & Krohn, J. (2018). Epidemiology and morphology of full-thickness macular holes. *Acta Ophthalmologica*, 96(4), 397-404. <https://doi.org/10.1111/aos.13618>
- Gass, J. D. M. (1988). Idiopathic senile macular hole: Its early stages and pathogenesis. *Archives of Ophthalmology*, 106(5), 629-639. <https://doi.org/10.1001/archophth.1988.01060130683026>
- Goto, K., Iwase, T., Yamamoto, K., Ra, E., & Terasaki, H. (2020). Correlations between intraretinal cystoid cavities and pre-and postoperative characteristics of eyes after closure of idiopathic macular hole. *Scientific Reports*, 10(1), Article 2310. <https://doi.org/10.1038/s41598-020-59295-7>
- Houly, J. R., Veloso, C. E., Passos, E., & Nehemy, M. B. (2017). Quantitative analysis of external limiting membrane, ellipsoid zone and interdigitation zone defects in patients with macular holes. *Graefes Archive for Clinical and Experimental Ophthalmology*, 255(7), 1297-1306. <https://doi.org/10.1007/s00417-017-3636-7>
- Jenchitr, W., Yokkampon, P., Ploysit, P., & Ausayakhun, S. (2024). The prevalence of visual impairment of the Elderly at University Eye Clinic. *Journal of Current Science and Technology*, 14(1), Article 9. <https://doi.org/10.59796/jcst.V14N1.2024.9>
- Kusuhara, S., Escaño, M. F. T., Fujii, S., Nakanishi, Y., Tamura, Y., Nagai, A., ... & Negi, A. (2004). Prediction of postoperative visual outcome based on hole configuration by optical coherence tomography in eyes with idiopathic macular holes. *American Journal of*

- Ophthalmology*, 138(5), 709-716.
<https://doi.org/10.1016/j.ajo.2004.04.063>
- La Cour, M., & Friis, J. (2002). Macular holes: Classification, epidemiology, natural history and treatment. *Acta Ophthalmologica Scandinavica*, 80(6), 579-587.
<https://doi.org/10.1034/j.1600-0420.2002.800605.x>
- Murphy, D. C., Al-Zubaidy, M., Lois, N., Scott, N., Steel, D. H., Qu, J., ... & Alvin, K. K. H. (2023). The effect of macular hole duration on surgical outcomes: An individual participant data study of randomized controlled trials. *Ophthalmology*, 130(2), 152-163.
<https://doi.org/10.1016/j.ophtha.2022.08.028>
- Oh, J., Smiddy, W. E., Flynn, H. W., Gregori, G., & Lujan, B. (2010). Photoreceptor inner/outer segment defect imaging by spectral domain OCT and visual prognosis after macular hole surgery. *Investigative Ophthalmology & Visual Science*, 51(3), 1651-1658.
<https://doi.org/10.1167/iovs.09-4420>
- Ozturk, Y., Ağın, A., Kockar, N., Ay, N., Imamoglu, S., Ozcelik Kose, A., & Kugu, S. (2022). The importance of anatomic configuration and cystic changes in macular hole: Predicting surgical success with a different approach. *Current Eye Research*, 47(10), 1436-1443.
<https://doi.org/10.1080/02713683.2022.2096908>
- Radke, N. V., Ruamviboonsuk, P., Steel, D. H., Tian, T., Hunyor, A. P., Tsai, A. S., ... & Lam, D. S. (2025). Controversies, consensuses, and guidelines on macular hole surgery by the Asia-Pacific Vitreo-retina Society (APVRS) and the Asia-Pacific Academy of Professors in Ophthalmology (AAPPO). *Eye and Vision*, 12(1), Article 30.
<https://doi.org/10.1186/s40662-025-00446-0>
- Rezende, F. A., Ferreira, B. G., Rampakakis, E., Steel, D. H., Koss, M. J., Nawrocka, Z. A., ... & Duker, J. S. (2023). Surgical classification for large macular hole: Based on different surgical techniques results: The CLOSE study group. *International Journal of Retina and Vitreous*, 9(1), Article 4.
<https://doi.org/10.1186/s40942-022-00439-4>
- Ruiz-Moreno, J. M., Staicu, C., Piñero, D. P., Montero, J., Lugo, F., & Amat, P. (2008). Optical coherence tomography predictive factors for macular hole surgery outcome. *British Journal of Ophthalmology*, 92(5), 640-644. <https://doi.org/10.1136/bjo.2007.136176>
- Sinawat, S., Jumpawong, S., Ratanapakorn, T., Bhoomibunchoo, C., Yospaiboon, Y., & Sinawat, S. (2021). Efficacy of pars plana vitrectomy with internal limiting membrane peeling for treatment of large idiopathic full-thickness macular holes. *Clinical Ophthalmology*, 15, 521-529.
<https://doi.org/10.2147/OPHTH.S294190>
- The Royal College of Ophthalmologists. (2025). *Idiopathic full thickness macular holes: Clinical guideline*. Retrieved from <https://www.rcophth.ac.uk/resources-listing/idiopathic-full-thickness-macular-holes/>
- Venkatesh, R., Mohan, A., Sinha, S., Aseem, A., & Yadav, N. K. (2019). Newer indices for predicting macular hole closure in idiopathic macular holes: A retrospective, comparative study. *Indian Journal of Ophthalmology*, 67(11), Article 1857.
https://doi.org/10.4103/ijo.IJO_364_19
- Yang, J., Xia, H., Liu, Y., Wang, X., Yuan, H., Hou, Q., ... & Li, X. (2021). Ellipsoid zone and external limiting membrane-related parameters on spectral domain-optical coherence tomography and their relationships with visual prognosis after successful macular hole surgery. *Frontiers in Medicine*, 8, Article 779602.
<https://doi.org/10.3389/fmed.2021.779602>
- Yun, C., Oh, J., Hwang, S. Y., Togloom, A., Kim, S. W., & Huh, K. (2012). Morphologic characteristics of chronic macular hole on optical coherence tomography. *Retina*, 32(10), 2077-2084.
<https://doi.org/10.1097/IAE.0b013e31825620ba>