Xu *et al. BMC Ophthalmology* (2025) 25:173
https://doi.org/10.1186/s12886-025-04019-6

BMC Ophthalmology

RESEARCH

Open Access

Effect of autologous whole blood in surgery for full-thickness macular hole: a propensity score matching analysis

Zhengbo Xu[1], Yuelin Wang[2] and Youxin Chen[3,4*]

Abstract

Background Idiopathic full-thickness macular hole (FTMH) is a vision-threatening disease treated by the "gold standard" pars planar vitrectomy followed by internal limiting membrane peeling. This conventional surgical approach, while yielding a promising 90% closure rate, has a low success rate in large macular holes. Autologous blood has been proven to significantly enhance the healing process and has been introduced into ophthalmic surgeries. The aim of this study is to compare visual and anatomical outcomes of full-thickness macular holes with and without the use of autologous whole blood.

Methods This retrospective study included 150 patients (150 eyes) diagnosed with FTMH and underwent primary surgery during 2020–2022. Patients with a minimum of 12 months follow-up were divided into whole blood (WB) group ($n=22$) and control group ($n=128$). An 1:3 propensity score matching (PSM) was performed based on sex, age, cataract history, diabetes, hypertension, injury, minimum linear diameter (MLD), basal diameter (BD) and preoperative best-corrected visual acuity (BCVA). Postoperative BCVA and optical coherence tomography (OCT) findings were collected for postoperative analysis.

Results After 1:3 PSM, 22 patients in WB group were matched to 66 patients in control group. The demographic characteristics showed no significant difference except for the MLD in WB group being significantly larger than control group: 762.50 ± 353.11 μm compared to 505.91 ± 193.52 μm ($p=0.003$). Despite this unfavorable condition, all MHs were closed in the WB group, while in the control group 14 MHs (21.21%) remained open ($p<0.017$). The WB group showed significantly better postoperative mean BCVA than control group ($p=0.016$). Also, significantly more patients had improvement in BCVA by 0.2 logMAR or more after surgery in the WB group than in the control group ($p=0.05$). After surgery with WB, a rugged retinal surface was observed in MHs larger than 1000 μm via OCT imaging.

Conclusions The incorporation of PSM can greatly reduce the bias incurred by confounders in this retrospective study. The adjuvant use of WB significantly improves the functional and anatomical outcomes after MH surgery. Especially in patients with large MHs, WB can precipitate the proliferation and migration of Müller cells which ensures foveal structure restoration.

Keywords Autologous whole blood, Full-thickness macular hole, Propensity score matching

*Correspondence:
Youxin Chen
chenyx@pumch.cn

Full list of author information is available at the end of the article

Background

The full-thickness macular hole (FTMH) is defined as the defect of retinal tissue in the foveal region [1]. In pre-OCT era, Gass and Johnson [2, 3] first proposed clinical staging of FTMH based on morphological appearances. Over the past 2 decades, the invention of OCT allowed the acquisition of OCT-based anatomical data such as size of the hole, retinal layer structures, presence or absence of vitreomacular traction, which greatly improved our understanding of pathogenesis and progression of macular hole [4]. The current classic macular hole (MH) surgery involves pars plana vitrectomy (PPV), followed by internal limiting membrane (ILM) peeling and gas tamponade [5–7], in order to reduce the tractional force between vitreous cortex and the macular, restore normal foveal structure and eventually close the FTMH. While the classic surgery remains the gold standard for treatment of FTMH and is reported to have over 90% of closure rate [8–11], its success rate is noticeably lower in large, recurrent, and refractory MHs [11–13].

Autologous blood is blood sample acquired from patient's own system and is proposed to contain abundant growth factors such as EGF, TGF-β, IGF-1 and other cytokines that are essential for cell proliferation. After its success in accelerating tissue healing after orthopedic surgeries [14–16], autologous blood was introduced to the treatment of FTMHs. Since 1995, research about autologous blood showed macular closure rate can reach as high as 100%, superior to that of conventional surgery [17–19]. But still, the efficacy of autologous blood remains controversial, and some studies even disproved the benefits of autologous blood [20, 21]. A 1999 randomized trial [22] indicated that the injection of autologous blood did not improve postoperative visual acuity and findings from this pivotal study are still used as essential evidence against autologous blood. However, this single trial, along with many other studies, was completed in pre-OCT era without quantitative measurement of MHs so that we do not know if the MHs were large enough to yield significantly different results. Thus, we conducted propensity score matching (PSM) between groups treated with and without autologous blood to analyze visual and anatomical outcomes based on modern surgical and examination techniques.

Methods

Subjects

We retrospectively reviewed the medical records and imaging information of 150 patients who were diagnosed with FTMH and underwent primary surgery at Department of Ophthalmology at Peking Union Medical College Hospital, Beijing, China, between October 2020 and July 2022. The whole blood (WB) group included 22 patients operated with the use of autologous blood. The rest of 128 patients who underwent conventional surgery formed a control group. All patients were operated by two highly skilled surgeons: YC and YZ.

The inclusion criteria were FTMH previously not operated; followed for at least 12 months; minimum linear diameter (MLD) of the hole > 250 μm (some patients with MLD < 250 μm but had abnormally large basal dimeter were also included). The exclusion criteria were history of vitreoretinal surgeries; any concurrent ocular diseases (except for cataract and pseudophakia). Demographic characteristics including age, sex, other chronic diseases (diabetes and hypertension), cataract history, injury, MLD and basal diameter (BD) of the hole, eye pressure, pre- and post-operative best-corrected visual acuity (BCVA).

Examination technique

BCVA data was collected by using Snellen chart and was converted into logarithm of minimal angle of resolution (logMAR). OCT examinations were performed with Intalight *van Gogh* OCT both pre- and post-operatively. The MLD and BD were acquired utilizing the built-in caliper function of the van Gogh software, preoperatively. We evaluated MH closure and retinal microstructures based on the OCT images acquired post-operatively.

Surgical strategy

All patients underwent standard 3-port 25G PPV (Fig. 1A). Patients were placed under retrobulbar anesthesia. After core vitrectomy, the surgeons injected 0.1-0.2 ml 0.125% indocyanine green (ICG) solution around the MH and washed out in less than 10 s to avoid excessive ICG remanent at MH area. Once the ILM can be clearly visualized, it was removed with vitreous forceps (Fig. 1B) at an area of 1 × 2 disk diameter around the MH. For the autologous blood group, autologous whole blood (WB) was collected from the peripheral venous system (median cubital vein at large) during the surgery, and WB was applied with a vitrectomy back-flush needle (Fig. 1C) to cover the MH area immediately, the amount of WB applied depends on the size of MH. Intraocular tamponade was performed using perfluoropropane [C3F8] tamponade agent. All patients were instructed to maintain the face-down proning position for at least 3 days after surgery.

Outcomes

The primary outcome was the closure of MH within 12 months postoperatively, elevated/open MHs were deemed anatomical failures in this study. Secondary outcomes were postoperative BCVA at 12 months and retinal microstructure. In our analysis of retinal microstructure, particular attention was directed towards gliosis, characterized by the presence of intraretinal

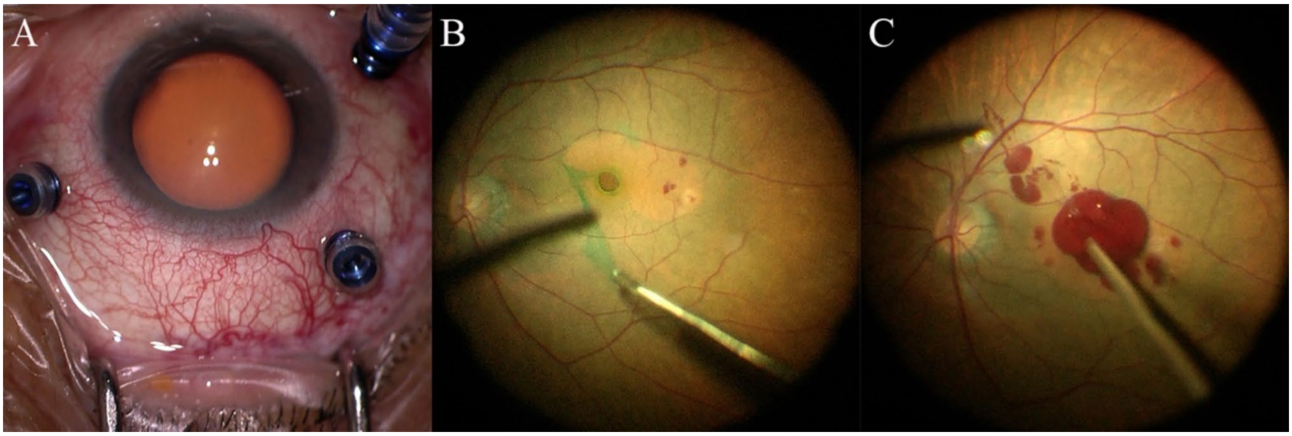

Fig. 1 Surgical strategy for WB group. (**A**) 3-port 25G pars-planar vitrectomy. (**B**) ILM peeling. (**C**) Application of WB via vitrectomy back-flush needle

hyperreflective lesions located in the foveal region. Additionally, we assessed the integrity of the ellipsoid zone (EZ) and the external limiting membrane (ELM), which were identified by the presence of continuous reflective lines within the respective EZ and ELM layers. Restoration of the photoreceptor layer was defined by the presence of continuous reflection line at EZ.

Statistical analysis

All statistical analysis was performed using R 4.3.2 software (R Foundation for Statistical Computing, Vienna, Austria) and Excel (Microsoft). To minimize the influence of confounders, an 1:3 matching between the WB and control group was performed using the propensity scores [23, 24] estimated by a multivariable logistic regression model. Nearest-neighbor matching was done by the R package "MatchIt" with sex, age, cataract history, diabetes, hypertension, injury, MLD, BD and preoperative BCVA as covariates. Continuous variables were presented as mean and standard deviation (SD), while categorical variables were presented as number (n) and frequencies (%). We used unpaired Student's t-test or the Mann–Whitney U test for continuous variables and Fisher's exact test for categorical variables. $P < 0.05$ was considered statistically significant.

Results

Demographic and comparison of the WB and control group

As shown in Table 1, we compared the clinical and demographic characteristics between the WB and control groups. Among the 150 study participants, 22 patients (14.67%) and 128 (85.33%) patients underwent WB-approach and conventional surgery, respectively (Table 1). There was no significant difference in age, eye pressure, cataract history and other chronic disease condition between two groups (all $p > 0.05$) (Table 1). The WB group showed significantly greater MLD and BD (Table 1). Preoperative BCVA was significantly higher for the control group (Table 1).

After 1:3 PSM, 22 patients in the WB group were matched to 66 patients in the control group. There were no significant differences in the aforementioned matching covariates between the two surgical approach groups, except for MLD which was significantly distinct between the WB and control groups.

Anatomical closure

In both groups, there were no serious complications after the surgery. Despite the significantly worse parameter of MH, that is, a larger preoperative MLD, the anatomical results in the WB group turned out to be better than in the controls. All patients in the WB group could achieve complete MH closure, while only 52 patients (78.79%) in the control group had MH closed after surgery (the difference is significant: $p = 0.017$, Table 2). It should be noted that the WB approach ensured success closure of all 17 patients with MLD more than 600 μm, including 2 patients with MLD larger than 1000 μm. Although in most cases the unclosed MHs in control group were large, there were no MH with MLD above 1000 μm, and there were also 2 medium [4] MHs (343 μm, 377 μm) remained open after surgery.

Postoperative BCVA

All patients in the WB and control group had transparent optic media at the end of the follow-up period. Both groups showed significant change from preoperative BCVA ($p < 0.001$ for both, Mann–Whitney U test). The patients in WB group started with MHs of larger sizes, but had significantly better mean postoperative BCVA (Table 2). The number of patients with BCVA improvement in two groups also differs significantly, as all 22 patients (100.00%) in the WB group showed improvement while only 48 patients (72.72%) improved their BCVA in the control group (Table 2). We further

Table 1 Clinical and demographic characteristics of all patients before and after PSM

Characteristics	Before matching			After matching		
	WB	Control	*p* value	WB	Control	*p* value
Total, n (%)	22 (14.67)	128 (85.33)		22 (25.0%)	66 (75.0%)	
Age (y), mean (SD)	60.00 (11.86)	60.17 (10.16)	0.949[a]	60.00 (11.86)	59.59 (10.59)	0.886[a]
Sex						
Female, n (%)	20 (90.90)	87 (67.97)	0.039[b]	20 (90.90)	54 (81.82)	0.503[b]
Male, n (%)	2 (9.10)	41 (32.03)		2 (9.10)	12 (18.18)	
MLD of the hole (μm), mean (SD)	762.50 (353.11)	424.48 (221.02)	< 0.001[a]	762.50 (353.11)	505.91 (193.52)	0.003[a]
Basal diameter (BD) of the hole (μm), mean (SD)	1158.16 (523.42)	853.40 (358.18)	0.015[a]	1158.16 (523.42)	1020.47 (361.68)	0.262[a]
Eye pressure (mmHg), mean (SD)	15.91 (2.24)	15.72 (2.63)	0.964[c]	15.91 (2.24)	15.62 (2.71)	0.722[c]
Cataract history, n (%)	15 (68.18)	79 (61.72)	0.639[b]	15 (68.18)	45 (68.18)	1.000[b]
Other chronic diseases						
Diabetes, n (%)	1 (4.54)	11 (8.59)	1.000[b]	1 (4.55)	4 (6.06)	1.000[b]
Hypertension, n (%)	11 (50.00)	37 (28.91)	0.081[b]	11 (50.00)	28 (42.42)	0.622[b]
Preoperative BCVA (logMAR), mean (SD)	1.22 (0.29)	1.08 (0.47)	0.038[c]	1.22 (0.29)	1.21 (0.48)	0.639[c]

BCVA best-corrected visual acuity, *logMAR* logarithm of minimal angle of resolution, *MLD* minimum linear diameter, *SD* standard deviation, WB whole blood, *y* year

[a]Unpaired Student's t-test. [b]Fisher's exact test. [c]Mann–Whitney U test

Table 2 Postoperative outcomes of the matched patients

Outcomes	WB	Control	*p* value
MH Closure, n (%)	22 (100.00)	52 (78.79)	< 0.017[a]
Postoperative BCVA (logMAR), mean (SD)	0.73 (0.14)	0.97 (0.46)	0.016[b]
BCVA improvement, n (%)	22 (100.00)	48 (72.72)	0.005[a]
Improvement by 0.2 logMAR or more, n (%)	21 (95.45)	36 (75.00)	0.05[a]
Presence of gliosis, n (%)	20 (90.91)	43 (65.15)	0.028[a]
Presence of EZ, n (%)	19 (86.36)	39 (59.09)	0.021[a]

[a]Fisher's exact test. [b]Mann–Whitney U test

analyzed the number of patients with BCVA increased by 0.2 logMAR or more, and the results indicated that the WB group had more patients with greater improvement than the control group (21, 95.45% and 36, 75.00%, respectively, $p = 0.05$, Table 2). It is of importance of the fact that 16 patients with MLD larger than 600 (up to 1415) μm acquired high functional results.

Retinal microstructure

OCT images were collected for all patients to monitor the retinal microstructure restoration process. As discussed above, all patients in the WB group had their MHs closed after surgery, and the postoperative OCT images indicated the restoration of continuity of retinal layers. However, for MHs over 1000 μm (Fig. 2. A, B) the inner retinal layers tended to have rugged shapes (Fig. 2. C, D) instead of the normal concave shape at foveal region. There were 14 patients in the control group who failed to have MHs closed. The OCT 12 months after surgery showed little narrowing of MHs (Fig. 3. C, D) compared to its preoperational state (Fig. 3. A, B), and there were 4 patients with enlarged MHs after surgery. The presence of gliosis was found in 20 patients (90.91%) in WB group, while the presence of gliosis was found in 43 patients (65.15%) in control group. The presence of an EZ line in the foveal area was observed in 19 patients (86.36%) in the WB group (Fig. 4), while the presence of an EZ line was observed in 39 patients (59.09%) in the control group.

Discussion

Blood derived products have been extensively used in ophthalmic practices ranging from ocular surface to fundus [25, 26]. For MH surgery, multiple attempts have been made, such as adjuvant use of autologous serum [27], fibrin glues [28], autologous platelet concentrates (APC) [21, 29], to facilitate the proliferation of retinal tissues. Among them, the APC was considered prospective and yielded positive results in different research [26]. Oddly, as the source of all those blood derivatives, autologous whole blood itself was scarcely reported [17, 18] and was mainly considered an alternative for the traditional indocyanine green [30] when it comes to

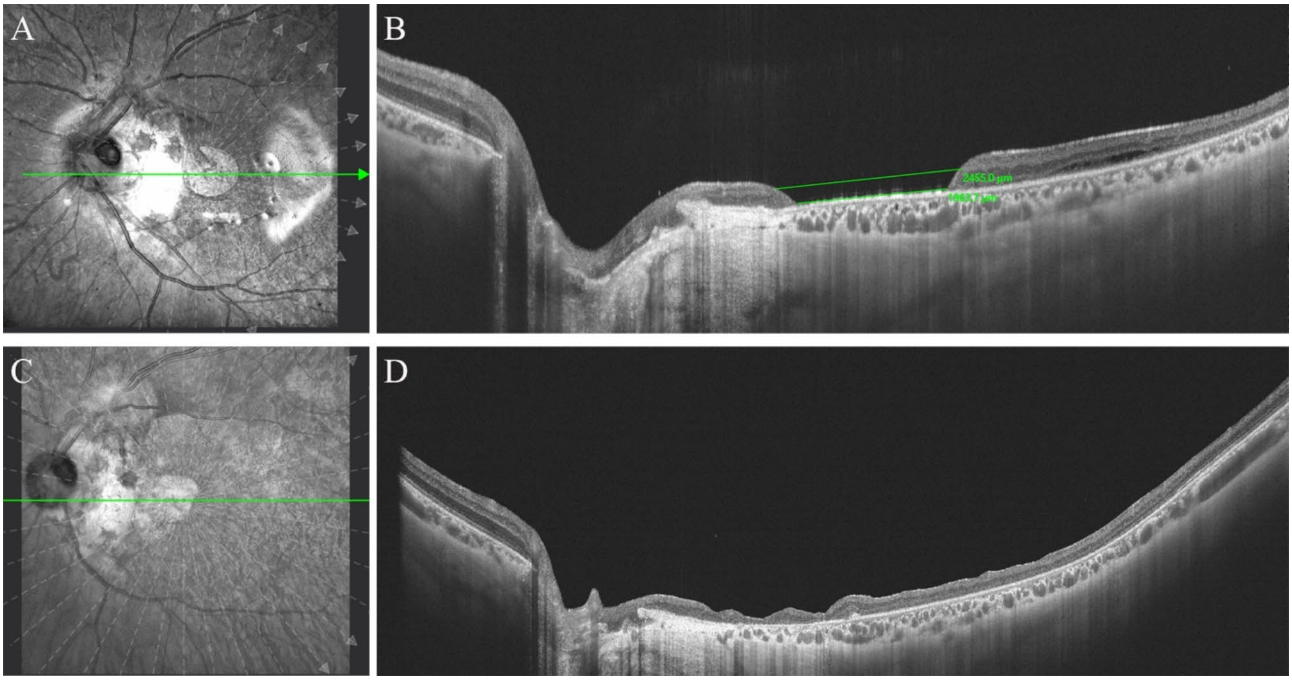

Fig. 2 Optical coherence tomography images taken before (**A**, **B**) and 12 months after (**C**, **D**) surgery with whole blood. The initial MLD was 1963.7 µm (B). After surgery, the macular hole was closed, leaving "rugged" retinal surface (D)

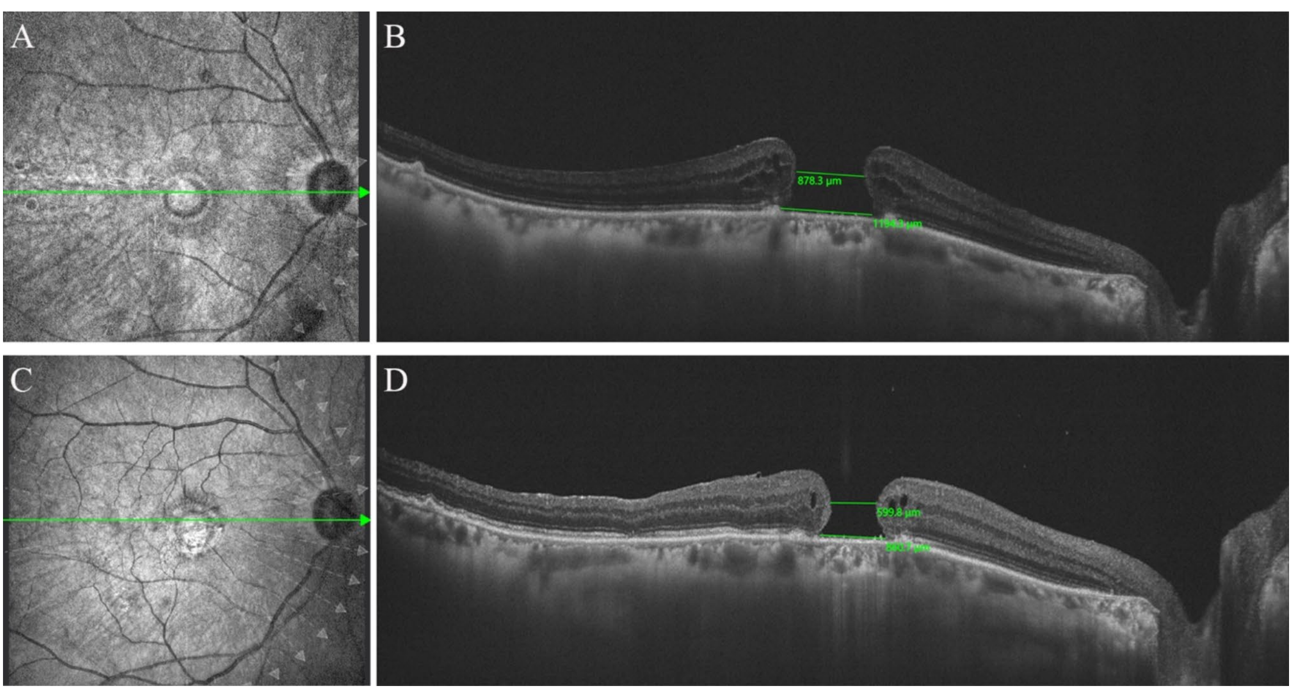

Fig. 3 Optical coherence tomography images taken before (**A**, **B**) and 12 months after (**C**, **D**) conventional surgery. The initial MLD was 878.3 µm (B). After surgery, the macular hole was not closed leaving a 599.8 µm opening (D)

contouring the macular area. Purtskhvanidzea et al. [17] conducted a study to compare the efficacy of APC or WB after revitrectomy and claimed that WB yielded low MH closure rate and thus cannot be applied to patients with MH. However, their results were based on the outcome of patients after revitrectomy, which means WB was not applied in their primary surgery, should their apply WB in the first place, different results might be acquired. Preparation of APC usually involves the following steps: the extraction of peripheral whole blood from patient,

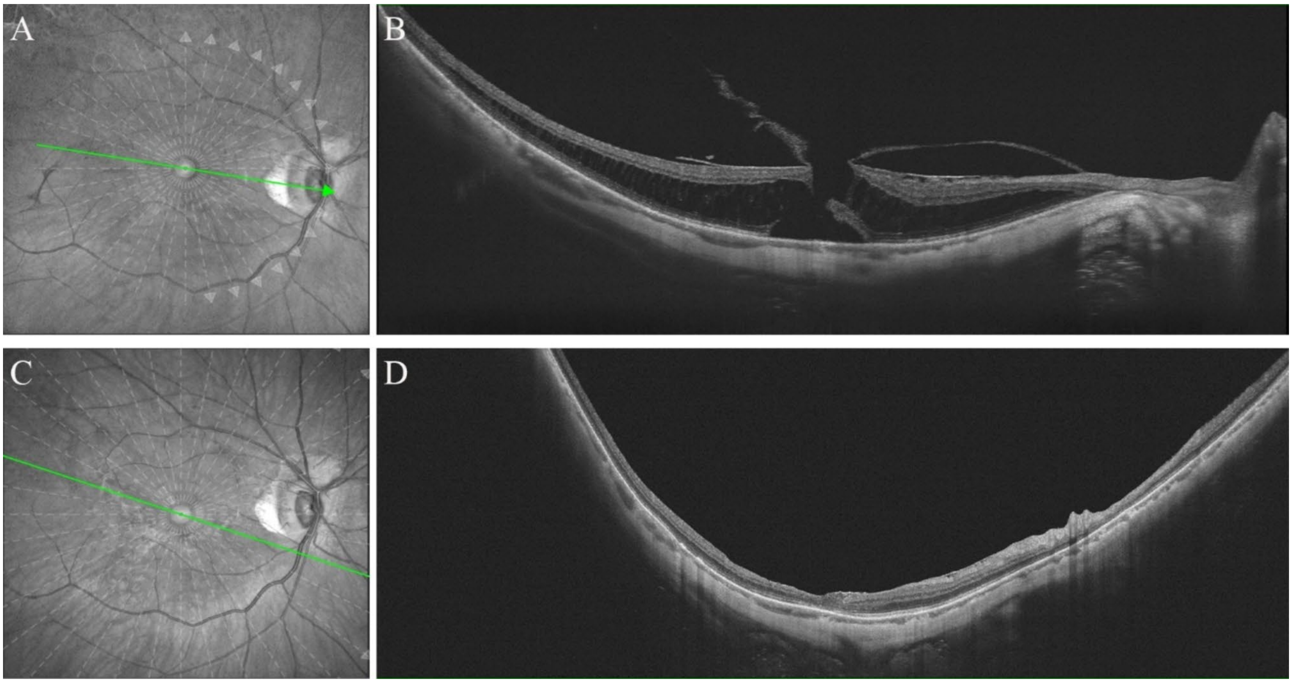

Fig. 4 Optical coherence tomography images taken before (**A**, **B**) and 12 months after (**C**, **D**) surgery with whole blood. Macular hole (B) was closed with visible EZ line at foveal area (D)

centrifugation to separate blood components, extraction of platelet concentrate, and each step has the potential to contaminate the blood sample which could lead to serious complications such as endophthalmitis [31, 32]. On the contrary, utilization of WB can waive these additional efforts by simply extracting WB sample into a sterilized syringe and immediately dropping onto the MH to be closed. Also, this swift process can be done within 3 min during the surgery without worrying about sample clotting and thus an anticoagulant, which may have unforeseeable effect on the intraocular microenvironment, will not be needed. In a recent study, Lu et al. [33] investigated autologous blood membrane transplantation as a new method for the treatment of refractory MHs: 5 ml autologous blood was extracted from patients, compressed and then solidified into a membrane which will be trimmed and plugged into the MH. They reported 100% HM closure rate in the treatment group, indicating autologous blood and its derivatives have satisfying curative effect. However, a risk associated with this solid form of autologous blood is that the trimmed membrane may not perfectly align with the shape of MH, thus cannot make full contact with the MH. Direct application of WB, in its liquid state, offers advantages in terms of simpler preparation and potentially improved efficacy compared to membrane transplantation. There are other studies that are in favor of intraoperative usage of WB, for example Lyu et al. [18] confirmed that WB may significantly increase closure rate in patients with refractive MHs by comparing the closure rate and postoperative BCVA between two groups. However, in addition to the conventional ILM peeling, their experimental group (WB group) underwent internal limiting membrane transplantation. This particular surgical method itself is an effective way to facilitate MH closing [34], thus the supposedly high closure rate may not be due to the use of whole blood.

To our knowledge, this study is the first to compare the results of conventional MH surgery with and without the use of WB by PSM analysis. In this retrospective study, we identified multiple demographic characteristics that may influence the final result. In another word, the difference in outcome is likely to reflect the difference in baseline conditions rather than the real treatment effect. This problem can be addressed by matching patients in treatment and control group with similar baseline conditions. The normal multivariable regression model can handle only restricted number of confounders, but with PSM the number of input confounders is not limited. Matching simultaneously on several confounders can be very complex, but we can shrink all confounders into a single value called propensity score (PS) so that the matching process can be more intuitive and convenient. After matching with PS, the outcome between treatment and control groups is more likely to give an unbiased estimate of treatment effect. The results of this study illustrate the benefits of utilizing WB as a surgical aid material compared to conventional ILM peeling operation. The use of WB achieved anatomical closure of MHs with large MLD (some even over 1000 μm), which serve as the basis for using WB in the primary surgery of MHs. Also, the infrequent cases of unfavorable anatomical results of conventional surgery for small and medium-sized MHs further brings out the importance of using WB.

We found out that visual function, measured by postoperative BCVA, at the final follow-up session was significantly higher in patients underwent surgery with the use of WB compared to conventional surgery. This finding is the opposite of the result of Hoerauf's study [35], which reported low MH closure rate (36%) and decrease of visual acuity after WB application. However, Hoerauf's study incorporated a so called "no-touch-technique" which is different from the conventional surgery in that it does not include ILM delamination. Without ILM peeling, the tractional force cannot be released, and eventually lead to poor functional and anatomical results. It is also worth pointing out that the visual acuity used to assess functional result was measured only 3 months after surgery, which was not long enough for gradual functional recovery [36]. Given these possible drawbacks, this study cannot serve as evidence against the use of WB.

We further investigated retinal microstructure restoration using OCT scanning. Our findings revealed a significantly stronger presence of gliosis and EZ line in the foveal area of the WB group compared to the control group ($p = 0.028$ and $p = 0.021$). This aligns with Hu et al.'s [37] study, which showed a positive correlation between better BCVA and the presence of gliosis and EZ line. We also noticed that there were a few patients with MHs persisted after conventional surgery, and 4 patients even had enlarged MHs at the end of the follow up period. The closure of MH is mediated by the proliferation of Müller cells, which propels centripetal displacement of photoreceptor cells [38]. Even after ILM peeling, some MHs are too large for Müller cells to proliferate and to form a tissue bridge across the MHs [39]. With the addition of WB, along with various growth factors contained in it, the migratory capability of Müller cells can be greatly augmented [40]. As a result, Müller cells can quickly proliferate and seal the MHs.

This study has limitations. This study is not randomized, the patients in WB group had larger MHs than the control group. We try to solve this imbalance with PSM, but the difference of MLD between two groups remain considerably large. However, this difference actually acts in favor of our conclusion. The WB group had much larger MHs to start with but nevertheless achieved much better functional and anatomical results, which further enhanced the conclusion that WB can improve postoperative outcome. But still, different matching methods could be explored, such as optimal pair or generic matching, to enhance matching quality.

The number of patients enrolled in the WB group was relatively small ($n = 22$) compared to 128 patients in the control group. But with PSM we made it possible to compare the functional and anatomical outcomes with the controls. Still, further randomized studies with large group numbers are needed to verify the results of the current study.

Conclusions

The results of this study suggest that adjuvant use of WB could improve postoperative BCVA and MH closure rate, especially in patients with large MHs. In addition, we illustrated that intraoperative WB sample collection is more sterile and convenient than APC, rendering WB a safe and effective surgical method. Also, The incorporation of PSM can greatly reduce the bias incurred by confounders in this retrospective study.

Abbreviations

BCVA	Best-corrected visual acuity
BD	Basal diameter
ELM	External limiting membrane
EZ	Ellipsoid zone
FTMH	Full-thickness macular hole
ICG	Indocyanine green
ILM	Internal limiting membrane
logMAR	Logarithm of minimal angle of resolution
MH	Macular hole
MLD	Minimum linear diameter
OCT	Optical coherence tomography
PPV	Pars plana vitrectomy
PSM	Propensity score matching
SD	Standard deviation
WB	Whole blood

Acknowledgements
Zhengbo Xu would like to thank Jiapeng Zhao for his advice on data analysis.

Author contributions
ZX drafted the manuscript and contributed to data acquisition and analysis. YW contributed to manuscript revision and data acquisition. YC contributed to image evaluation and manuscript revision. ZX and YW contributed equally to this article. All authors read and approved the final manuscript.

Funding
Not applicable.

Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
This study was approved by the Institutional Review Board of Peking Union Medical College Hospital (reference number: HS-1538) and the requirement for informed consent was waived. The study was conducted in accordance to the tenets of the Declaration of Helsinki.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]4+4 Medical Doctor Program, Chinese Academy of Medical Sciences & Peking Union Medical College, No.9 Dongdansantiao Street, Dongcheng District, Beijing 100730, China
[2]Department of Ophthalmology, Peking University Eye Center, Peking University Third Hospital, No. 49 Garden North Road, Haidian, Beijing 100191, China
[3]Department of Ophthalmology, Peking Union Medical College Hospital, Chinese Academy of Medical Sciences, Beijing 100730, China
[4]Key Laboratory of Ocular Fundus Diseases, Chinese Academy of Medical Sciences & Peking Union Medical College, Beijing 100730, China

Received: 15 October 2024 / Accepted: 26 March 2025
Published online: 07 April 2025

References

1. Ho AC, Guyer DR, Fine SL. Macular Hole[J]. Surv Ophthalmol. 1998;42(5):393–416.
2. Gass JDM. Idiopathic senile macular hole[J]. Arch Ophthalmol. 1988;106(5):629.
3. Johnson RN, Gass JDM. Idiopathic Macular Holes[J]. Ophthalmol. 1988;95(7):917–24.
4. Duker JS, Kaiser PK, Binder S, et al. The international vitreomacular traction study group classification of vitreomacular adhesion, traction, and macular hole[J]. Ophthalmology. 2013;120(12):2611–9.
5. Yu Y, Liang X, Wang Z et al. Internal limiting membrane peeling and air tamponade for stage III and stage IV idiopathic macular hole[J]. Retina. 1970;40(1):66–74.
6. Cornish KS, Lois N, Scott NW, et al. Vitrectomy with internal limiting membrane peeling versus no peeling for idiopathic full-thickness macular hole[J]. Ophthalmology. 2014;121(3):649–55.
7. Dervenis N, Dervenis P, Sandinha T, et al. Intraocular tamponade choice with vitrectomy and internal limiting membrane peeling for idiopathic macular hole[J]. Ophthalmol Retina. 2022;6(6):457–68.
8. Christensen UC. Value of internal limiting membrane peeling in surgery for idiopathic macular hole and the correlation between function and retinal morphology[J]. Acta Ophthalmologica. 2009;87(thesis2):1–23.
9. Bainbridge J, Herbert E, Gregor Z. Macular holes: vitreoretinal relationships and surgical approaches[J]. Eye. 2008;22(10):1301–9.
10. Lai MM, Williams G A. Anatomical and visual outcomes of idiopathic, macular hole surgery with internal limiting membrane removal using low-concentration indocyanine green[J]. Retina. 2007;27(4):477–82.
11. Wang H. Parafoveal retinal massage combined with autologous blood cover in the management of giant, persistent or recurrent macular holes[J]. Int J Ophthalmol. 2020;13(11):1773–9.
12. Riding G, Teh BL, Yorston D, et al. Comparison of the use of internal limiting membrane flaps versus conventional ILM peeling on post-operative anatomical and visual outcomes in large macular holes[J]. Eye. 2024;38(10):1876–81.
13. Arda H, Maier M, Schultheiß M, et al. Advances in management strategies for large and persistent macular hole: an update[J]. Surv Ophthalmol. 2024;69(4):539–46.
14. Li F, Li Y, Qiao C, et al. Topical use of platelet-rich plasma can improve the clinical outcomes after total knee arthroplasty: a systematic review and meta-analysis of 1316 patients[J]. Int J Surg. 2017;38:109–16.
15. Everts PAM, Devilee RJJ, Oosterbos CJM, et al. Autologous platelet gel and fibrin sealant enhance the efficacy of total knee arthroplasty: improved range of motion, decreased length of stay and a reduced incidence of arthrofibrosis[J]. Arthroscopy: Knee Surgery, Sports Traumatology. 2007;15(7):888–94.
16. Kuang M, Han C, Ma J, et al. The efficacy of intraoperative autologous platelet gel in total knee arthroplasty: a meta-analysis[J]. Int J Surg. 2016;36:56–65.
17. Purtskhvanidze K, Frühsorger B, Bartsch S, et al. Persistent full-thickness idiopathic macular hole: anatomical and functional outcome of revitrectomy with autologous platelet concentrate or autologous whole blood[J]. Ophthalmologica. 2017;239(1):19–26.
18. Lyu W-J, Ji L-B, Xiao Y, et al. Treatment of refractory giant macular hole by vitrectomy with internal limiting membrane transplantation and autologous blood[J]. Int J Ophthalmol. 2018.
19. Liggett PE, Skolik DSA, Horio B, et al. Human autologous serum for the treatment of full-thickness macular holes[J]. Ophthalmology. 1995;102(7):1071–6.
20. Ezra E, J.Gregor Z. Surgery for idiopathic full-thickness macular hole[J]. Arch Ophthalmol. 2004;122(2):224.
21. Mulhern MG, Cullinane A, Cleary PE. Visual and anatomical success with short-term macular tamponade and autologous platelet concentrate[J]. Graefe's Archive Clin Experimental Ophthalmol. 2000;238(7):577–83.
22. Paques M, Chastang C, Mathis A, et al. Effect of autologous platelet concentrate in surgery for idiopathic macular hole[J]. Ophthalmology. 1999;106(5):932–8.
23. ROSENBAUM P R, RUBIN DB. The central role of the propensity score in observational studies for causal effects[J]. Biometrika. 1983;70(1):41–55.
24. D'Agostino RB. Propensity score methods for bias reduction in the comparison of a treatment to a non-randomized control group[J]. Stat Med. 1998;17(19):2265–81.
25. Anitua E, Muruzabal F, Tayebba A et al. Autologous serum and plasma rich in growth factors in ophthalmology: preclinical and clinical studies[J]. Acta Ophthalmol. 2015;93(8).
26. Nugent RB, Lee GA. Ophthalmic use of blood-derived products[J]. Surv Ophthalmol. 2015;60(5):406–34.
27. Kung Y-H, Wu T-T. The effect of autologous serum on vitrectomy with internal limiting membrane peeling for idiopathic macular hole[J]. J Ocul Pharmacol Ther. 2013;29(5):508–11.
28. Lopezcarasa-Hernandez G, Perez-Vazquez J-F, Guerrero-Naranjo J-L et al. Versatility of use of fibrin glue in wound closure and vitreo-retinal surgery[J]. Int J Retina Vitreous. 2021;7(1).
29. Shpak AA, Shkvorchenko DO, Krupina EA. Surgical treatment of macular holes with and without the use of autologous platelet-rich plasma[J]. Int Ophthalmol. 2021;41(3):1043–52.
30. Lai C-C, Hwang Y-S, Liu L, et al. Blood-assisted internal limiting membrane peeling for macular hole repair[J]. Ophthalmology. 2009;116(8):1525–30.
31. Lo Giudice G, Alessandria A, Imburgia A, et al. Unilateral macular hole in a patient with retinitis pigmentosa treated with cover flap technique with the use of platelet-rich plasma under air tamponade: case report[J]. RETINAL Cases & Brief Reports. 2023.
32. Cheung CMG, Munshi V, Mughal S, et al. Anatomical success rate of macular hole surgery with autologous platelet without internal-limiting membrane peeling[J]. Eye. 2005;19(11):1191–3.
33. Lu G, Zeng S, Huang R, et al. Platelet-rich fibrin membrane transplantation for the treatment of highly myopic macular hole retinal detachment[J]. Ophthalmol Therapy. 2024;13(9):2425–43.
34. Morizane Y, Shiraga F, Kimura S, et al. Autologous transplantation of the internal limiting membrane for refractory macular holes[J]. Am J Ophthalmol. 2014;157(4):861–e8691.
35. Hoerauf H, Klüter H, Joachimmeyer E, et al. Results of vitrectomy and the no-touch-technique using autologous adjuvants in macular hole treatment[J]. Int Ophthalmol. 2001;24(3):151–9.
36. Purtskhvanidze K, Treumer F, Junge O, et al. The long-term course of functional and anatomical recovery after macular hole surgery[J]. Volume 54. Investigative Opthalmology & Visual Science; 2013. p. 4882. 7.
37. Hu X-T, Pan Q-T, Zheng J-W, et al. Foveal microstructure and visual outcomes of myopic macular hole surgery with or without the inverted internal limiting membrane flap technique[J]. Br J Ophthalmol. 2018;103(10):1495–502.
38. Bringmann A, Unterlauft JD, Barth T, et al. Müller cells and astrocytes in tractional macular disorders[J]. Prog Retin Eye Res. 2022;86:100977.
39. Bringmann A, Duncker T, Jochmann C et al. Spontaneous closure of small full-thickness macular holes: presumed role of Müller cells[J]. Acta Ophthalmol. 2019;98(4).
40. Wu A-L, Liu Y-T, Chou H-D, et al. Role of growth factors and internal limiting membrane constituents in Müller cell migration[J]. Exp Eye Res. 2021;202:108352.

Publisher's note