IATROGENIC RETINAL BREAKS IN 25-GAUGE VITRECTOMY UNDER AIR COMPARED WITH THE STANDARD 25-GAUGE SYSTEM FOR MACULAR DISEASES

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Purpose: To evaluate the incidence rates of iatrogenic retinal breaks in eyes that underwent 25-gauge vitrectomy under air compared with 25-gauge standard vitrectomy for idiopathic macular holes or idiopathic epiretinal membranes.

Methods: In this retrospective, comparative interventional study, 435 eyes were enrolled. In all patients after core vitrectomy and epiretinal/inner limiting membrane peeling, complete vitrectomy of the base was performed, respectively under air (air group) or under fluid infusion (standard group).

Results: The number of eyes with iatrogenic retinal breaks was significantly lower in the air group than in standard group (4/197 and 16/238, 2% and 7%, respectively; P = 0.035). A postoperative retinal detachment developed in 2 eyes (1%) in the standard group, and in no eyes of the air group (0%). Factors related to the occurrence of retinal breaks were surgically induced posterior vitreous detachment (P = 0.006), standard vitrectomy (P = 0.023), and surgery for macular hole (P = 0.030).

Conclusion: The 25-gauge vitrectomy under air is associated with a lower incidence rate of retinal breaks compared with the standard 25-gauge vitrectomy.

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Epiretinal membrane (ERM) and macular hole (MH) are characteristic retinal disorders that affect otherwise healthy elderly individuals.¹

Recent advances in small-gauge transconjunctival sutureless vitrectomy have now changed the management of these patients.²–⁶ This technique is more and more used by many surgeons on the basis of advantages compared with traditional techniques, such as shorter operating times, reduced surgical trauma, postoperative comfort, reduced astigmatism, and faster visual recovery.⁷,⁸

Continuous advances in surgical techniques have improved the outcomes and reduced the risks of vitreoretinal surgery; in case of macular diseases, this has decreased the threshold for surgery, and vitrectomy is currently performed in eyes with a relatively good visual acuity. However, despite this improved safety, rhegmatogenous retinal detachment secondary to iatrogenic peripheral retinal breaks remains a serious intraoperative and postoperative complication, which requires additional surgery and would induce poor visual results.⁹–¹²

The more common causes of intraoperative retinal breaks are the insertion of surgical instruments causing traction on the adjacent vitreous base, incarceration of vitreous in the sclerotomy site during the withdrawal of instruments, traction on the peripheral retina during the removal of vitreous base, and intraoperative induction of a posterior vitreous detachment (PVD)
have been reported. For postoperative retinal breaks, the shrinking and subsequent tearing of the incompletely removed peripheral vitreous have been advocated.

In an attempt to minimize the incidence of these complications, all sorts of prophylactic measures have been proposed. Scleral buckling, 360° laser treatment, or circular cryoretinopexy were deemed appropriate, but these in fact are quite invasive and impose risks of their own.

To limit these complications, some of us recently proposed a modification of the standard vitrectomy (American Society of Retinal Specialists 30th Annual Meeting; August 25–29, 2012). In this technique, pars plana vitrectomy is performed under the continuous infusion of air, instead of the balanced salt solution, leading to a better visualization and a safer removal of the vitreous base.

The aim of the present study was to evaluate the incidence of iatrogenic retinal breaks in 25-gauge vitrectomy under air and to compare it with standard 25-gauge vitrectomy.

Patients and Methods

Subjects

This is a retrospective, nonrandomized comparative interventional study. Medical records of all consecutive patients who underwent 25-gauge vitrectomy, at the Department of Ophthalmology of the University of Ancona, between November 1, 2008 and July 30, 2012 for either ERM or full-thickness idiopathic MH (Stages 2, 3, and 4 according to Gass classification) with a minimal follow-up of 6 months were reviewed.

From November 2008 to September 2010, all consecutive patients underwent 25-gauge standard vitrectomy (standard group), and from September 2010 to July 2012, all consecutive patients underwent 25-gauge vitrectomy under air (air group). If a patient had vitrectomy in both eyes, only the eye with previous surgery was included in the study.

In a database, the following parameters were collected: patient demographics, indication for vitrectomy, preexisting or surgically induced PVD, preoperative lens status (phakic, pseudophakic, or aphakic), axial length, combined vitrectomy and phacoemulsification, identification and location of intraoperative and postoperative peripheral iatrogenic retinal breaks, and postoperative rhegmatogenous retinal detachment.

The study was approved by the institutional ethics committee and all patients signed informed consents.

Eyes with secondary MH, preexisting retinal breaks and/or retinal detachment, diabetic retinopathy, age-related macular degeneration, vascular occlusion, retinal vasculitis, axial length >26 mm, or previous vitrectomy, were excluded from this study.

Preoperatively, each patient underwent a complete evaluation including best-corrected visual acuity determination, anterior segment examination, and dilated fundus examination using indirect ophthalmoscopy with scleral depression. The presence or absence of PVD was defined on biomicroscopic observation using a 78-diopter lens and B-scan ultrasound examination before surgery; axial length was assessed by A-scan ultrasound examination (Cinescan S “HF”; Quantel Medical, Le Brezet, France).

Surgical Technique

All patients underwent a 3-port 25-gauge vitrectomy by the same surgeon (C.M.) under general or local anesthesia, depending on the patient preference. Vitrectomy was performed with 25-gauge instruments and the Constellation Vision system (UHS Alcon Constellation; Alcon Laboratories, Inc, Fort Worth, TX) with a cut rate of 5,000 cuts per minute, a duty circle control, and up to 600 mmHg of linear aspiration. The 25-gauge sutureless trocar system by Alcon Laboratories, Inc was used for microincisions. All cases were performed using the Resight 700 (Carl Zeiss Meditec AG, Jena, Germany) wide-angle viewing system or the Binocular Indirect Ophthalmalmol Microscope wide-angle viewing system (BIOM; Oculus Inc, Wetzlar, Germany).

After thorough disinfection of the periorcular skin with povidone–iodine 5% and instillation of povidone–iodine into the inferior fornix, in phakic patients older than 50 years of age, a clear-cornea lens surgery with intraocular lens implantation was performed by using a standard phacoemulsification technique. Sclerotomies were placed 3.5 mm posterior to the limbus in the phakic eyes, and 3 mm in the pseudophakic or aphakic eyes; all were performed in a 30° fashion, parallel to the limbus. The infusion cannula was positioned in the inferotemporal quadrant, and superotemporal and superonasal sclerotomies were conducted near the 10-o’clock and 2-o’clock meridians. Vitrectomy started shaving the anterior vitreous.

Core vitrectomy was then performed and, if not already present, a PVD was induced. In those cases, the methodology involved the vitrectomy probe in a cutting-off mode, close to the optic nerve.

Epiretinal membrane peeling was carried out using end-gripping forceps. The internal limiting membrane was subsequently peeled at the surgeon’s discretion using brilliant blue G dye; the internal limiting membrane was usually incised and then peeled in a circumferential
manner to an area of two optic disk diameters on average around the fovea.

In the air group, after peeling, the fluid–air exchange was performed, with air infusion between 28 mmHg and 30 mmHg. The air highlighted a ring of vitreous in correspondence of the vitreous base because of the air bubble pushing the vitreous residue toward the retina; the residual vitreous was removed by placing the cutter port barely into the vitreous and shaving it until the interface profile was changed with the disappearance of the ring of vitreous. Particular attention was placed on performing a complete shaving of the vitreous from the internal sclerotomy site.

In case of poor visualization because of condensation of the posterior lens capsule, we irrigated the posterior capsule with the balanced salt solution using a needle, restoring a clear view. In case of the presence of air in an anterior chamber, viscoelastic was injected in the anterior chamber through a limbal incision.

In the standard group, after peeling, the vitreous was removed up to the far periphery under fluid infusion in all cases. The vitreous was meticulously removed around the ports and the infusion line.

After vitrectomy was completed, all patients underwent a full scleral-depressed peripheral retinal examination to assess the presence of retinal breaks. All retinal breaks detected intraoperatively were treated with endolaser photocoagulation.

On completion of the surgery, sulfur hexafluoride gas or air was used as a postoperative tamponade on the basis of the surgical indication.

**Examination**

Peripheral retinal breaks were defined as definite retinal breaks located between the midperiphery and the ora serrata. Indeterminate retinal lesions that resembled the retinal breaks were not included. Retinal breaks located anterior to the equator, and within 1 clock-hour on either side of a sclerotomy site were referred to as sclerotomy-related retinal breaks. Breaks that were located away from any of the sclerotomies were defined breaks elsewhere.\(^{11,16}\)

Postoperative examinations were routinely performed on postoperative Days 1, 7, and 15, and then in Months 1, 3, and 6.

**Data Analysis**

The differences between the patient groups were analyzed using the Student’s *t*-test and chi-square test. To investigate factors associated with the occurrence of a retinal break, logistic regression was used with or without break as the outcome, and age, lens status, axial length, indication for surgery, combined vitrectomy and phacoemulsification, and induced PVD were used as explanatory variables. Values of *P* < 0.05 were considered statistically significant. Statistical analysis was conducted using the SPSS 11.5.1 for Windows soft package (SPSS, Inc, Chicago, IL).

**Results**

Of the 506 eyes that underwent 25-gauge TSV, 435 eyes of 435 patients met the study inclusion criteria and were included in the study. The baseline demographic, clinical, and surgical characteristics of the enrolled patients are reported in Table 1.

Indication for surgery was MH in 138 eyes and ERM in 297 eyes; 197 eyes underwent vitrectomy under air and 238 eyes underwent standard vitrectomy.

There was no significant difference in the preoperative data between the two groups. The incidence of preexisting PVD was lower in MH cases than in ERM cases in both air group (39/68 and 94/129, 57.4% and 72.9%, respectively; *P* = 0.40) and standard group (37/70 and 121/168, 52.9% and 72%, respectively; *P* = 0.007).

The incidence rates of intraoperative and postoperative retinal breaks in the air group and standard group are summarized in Table 2.

Overall, retinal breaks were found in 4 of 197 eyes (2%) in the air group and 16 of 238 eyes (7%) in the standard group; the difference was statistically significant (*P* = 0.035).

In most of the cases, retinal breaks were detected intraoperatively: 4 of 197 in air group and 12 of 238 in standard group, and received intraoperative laser treatment.

Postoperatively, no eye had retinal breaks or rhegmatogenous retinal detachment in the air group, whereas retinal breaks were identified in 4 eyes (2%) of the standard group (1 eye at 1 week examination, 1 eye at 2 months, 2 eyes at 3 months); 2 eyes developed a retinal detachment and were treated successfully with vitrectomy.

Among the eyes treated for MH, the rate of eyes with retinal breaks was lower in the air group than in the standard group (2/68 [2.9%] and 8/70 [11.4%], respectively); however, the difference was not significant (*P* = NS). In eyes with ERM, the rate of eyes with retinal breaks was similar in the 2 groups (1.5% and 2.4%, respectively) (*P* = NS).

The distributions of the retinal breaks in the air group and standard group are shown in Table 3.

In the air group, the total number of retinal breaks was five (four eyes): one eye had two breaks. In the standard group, the total number of retinal breaks was
20 (16 eyes): 2 eyes had 2 retinal breaks, and 1 eye had 3 retinal breaks.

In the air group, two retinal breaks were sclerotomy-related and three were breaks elsewhere. In the standard group, 5 retinal breaks were sclerotomy-related and 16 were breaks elsewhere.

Factors related to the occurrence of retinal breaks were standard vitrectomy (0.012), surgically induced PVD ($P = 0.019$), and the presence of MH ($P = 0.030$), whereas axial length, lens status, combined surgery, and age were not predisposing factors in the incidence of breaks.

At 6 months after the surgery, the rate of cataract formation in phakic patients younger than 50 years of age was 60% in the air group (6/10), and 55% in the standard group (6/11) ($P = \text{NS}$).

**Discussion**

The aim of this study was to evaluate the incidence of iatrogenic retinal breaks in 25-gauge vitrectomy under air and to compare it with standard 25-gauge vitrectomy. We found that vitrectomy under air significantly reduces the occurrence of iatrogenic retinal breaks.

Despite the recent evolution of vitreoretinal surgical techniques, the incidence of retinal breaks is still
clinically significant; in small-incision vitrectomy, it has been reported in a range from 0% to 15.8% of the eyes.\textsuperscript{2–4,9–11,13,16–20} This variation could be explained by the different surgical indications for vitrectomy or different methods of identifying retinal breaks. In our study, the overall rate of eyes with iatrogenic retinal breaks was 4.6% (20 of 435 eyes), with a lower incidence in vitrectomy under air than in standard vitrectomy (2 vs. 6.7%); furthermore, no eyes had postoperative retinal break in the first group, whereas 4 eyes had postoperative retinal break in the standard group, and 2 of them developed a postoperative retinal detachment.

As a consequence of a vitrectomy, two types of iatrogenic peripheral retinal breaks have been described: those associated with entry sites and those occurring elsewhere in the retina.\textsuperscript{10,11,16} Entry site breaks are believed to be caused by traction on the vitreous base, either as a result of the insertion and removal of instruments during the surgery or as a complication of the vitreous becoming incarcerated in a sclerotomy.\textsuperscript{21} Retinal breaks elsewhere developing during vitrectomy generally result from traction to the retina by the vitreous cutter or have been described as a result of a PVD induced surgically.\textsuperscript{1,22} It has been shown that, in small-gauge vitrectomy, most of iatrogenic retinal breaks occur at sites other than the sclerotomy, with a low incidence of entry site breaks.\textsuperscript{2,10,11} Also in our study, retinal breaks occurred mainly at sites distant from sclerotomies, with a rate of retinal breaks elsewhere of 60% in the air group and 80% in the standard group. These observations confirm that, in small-gauge vitrectomy, breaks arise not only from traction at entry sites and intraocular manipulation but also from the process of separation of the vitreous from the peripheral retina during vitrectomy.

Favorable results of the vitrectomy under air, compared with traditional vitrectomy, may be related to two main advantages offered by air: the better intraoperative visualization and the safer removal of the vitreous base; both aspects are due to the physical properties of air inside the vitreous cavity. Air is an agent immiscible in aqueous media, as opposed to the vitreous and infusion fluid being all aqueous substances. This immiscibility is best referred to as interfacial surface tension; different liquids have different surface tension, which depends on the chemical characteristics of their molecules and their intermolecular attraction forces.\textsuperscript{23,24} For these reasons, the air–vitreous interface facilitates visualization of the vitreous base, and allows an easier shaving of the residual vitreous. Furthermore, air stabilizes the retina because of the inherent springlike properties of a compressible gas, against the aspiration force of the vitreous cutter, thereby reducing the possibility of iatrogenic retinal breaks; this is because of high surface tension between the vitreous and air, which is greater than all other agents used during the vitrectomy.\textsuperscript{23,24}

In our study, the incidence of retinal breaks was higher in eyes with MH (overall 12/138, 8.7%) than in those with ERM (overall 8/297, 2.7%). Similar results have been shown in previous reports\textsuperscript{1,16} that described a relationship between the induction of PVD and the occurrence of peripheral retinal breaks.

In eyes with surgically induced PVDs, a strong vitreous traction on the retina and adhesive power of the vitreoretinal interface, greater than in eyes with physiologic PVDs, has been described; in the latter, various age-related changes, such as the vitreous liquefaction and reduction of adhesion molecules on the vitreoretinal interface, reduce traction on the retina.\textsuperscript{25–27} In our study, the surgical induction of PVD was more frequent in MH eyes in both standard and air groups; however, the rate of eyes with retinal breaks was high only in the standard group. Because the same percentage of eyes had an induced PVD in both air and standard vitrectomy groups, this suggests that retinal breaks can develop during the removal of the peripheral vitreous because a more tenacious peripheral vitreoretinal adhesion can require a greater traction. The action of air, that contrasts the traction of vitreous cutting, can reduce the incidence of breaks.

Regarding postoperative retinal breaks, it was suggested that the high rate of intraoperative tears and postoperative retinal detachments encountered after 25-gauge vitrectomy were favored by inadequate peripheral vitrectomy because of the more flexible instruments and that the residual vitreous skirt could cause an anterior vitreoretinal traction and subsequent tears or retinal detachments.\textsuperscript{5,28} Although our study did not have a power sufficient to show significant differences, the largest number of postoperative retinal tears and retinal detachments in eyes undergoing standard vitrectomy could be related to the incomplete removal of the peripheral vitreous. The better view of the vitreous base under air, in combination with

| Table 3. Localization of Retinal Breaks in Eyes Treated With Airbag Vitrectomy or Vitrectomy Under Air |
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| **No. retinal breaks** | **Air Group** | **Standard Group** | **P** |
| Total, n | 5 | 20 |  |  |
| Breaks sclerotomy-related, n | 2 (40) | 4 (20) | NS |
| Breaks elsewhere, n (%) | 3 (60) | 16 (80) | NS |

*Chi-square test.
NS, not statistically significant.
the wide-angle viewing systems, allows a complete shaving of the peripheral vitreous, in particular from the internal sclerotomy site, significantly reducing the vitreous incarceration and a meticulous identification of all retinal breaks.

A limitation of this technique is that, although visualization of the retina can be improved with an air-filled eye, it can also be severely compromised in certain situations. In a pseudophakic eye with a disrupted posterior capsule, air can fog the intracocular lens and compromise the view.\(^\text{29}\) In addition, migration of air into the anterior chamber through zonular dialysis in pseudophakic and phakic eyes can severely compromise visualization of the posterior segment.\(^\text{29}\)

A major limitation of the study is that it is retrospective and lacks randomization. The two groups are disparate in time; therefore, we cannot exclude potential biases, for example, because of the learning curve of the surgeon with Constellation and advances in surgical technology. Moreover, the limited follow-up may have underestimated the true long-term risk of retinal detachment.

In conclusion, this study found that 25-gauge vitrectomy under air significantly reduced the rate of iatrogenic retinal break formation compared with the standard 25-gauge vitrectomy. This technique improves visualization of both peripheral retina and vitreous base interface, as well as stabilization of the retinal surface while shaving closely at the vitreous base. Vitrectomy under air minimizes surgical complications while still providing the potential for successful anatomical and visual results.

**Key words:** vitrectomy under air, epiretinal membrane, iatrogenic retinal breaks, macular hole.

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