Air Bubble–Induced High Intraocular Pressure After Descemet Membrane Endothelial Keratoplasty

Daniel Röck, MD, Karl Ulrich Bartz-Schmidt, MD, Tobias Röck, MD, and Efdal Yoeruek, MD

Purpose: To investigate the incidence and risk factors of pupillary block caused by an air bubble in the anterior chamber in the early postoperative period after Descemet membrane endothelial keratoplasty (DMEK).

Methods: A retrospective review was conducted in 306 eyes that underwent DMEK from September 2009 through October 2014 at the Tübingen Eye Hospital. Intraocular pressure (IOP) elevation was defined as a spike above 30 mm Hg. In the first 190 eyes, an intraoperative peripheral iridectomy was performed at the 12-o'clock position and in the other 116 eyes at the 6-o'clock position. If possible, reasons for IOP elevation were identified. For all eyes, preoperative and postoperative slit-lamp examinations and IOP measurements were performed.

Results: Overall, 30 eyes (9.8%) showed a postoperative IOP elevation within the first postoperative day. The incidence of IOP elevation was 13.9% (5/36) in the triple DMEK group, and 2 of 5 phakic eyes (40%) developed an air bubble–induced IOP elevation. All eyes presented with a de novo IOP elevation, associated in 25 patients with pupillary block from air anterior to iris and in 5 patients with angle closure from air migration posterior to the iris. All of them had an iridectomy at the 12-o'clock position.

Conclusions: A postoperative pupillary block with IOP elevation caused by the residual intraoperative air bubble may be an important complication that could be avoided by close and frequent observations, especially in the first postoperative hours and by an inferior peripheral iridectomy and an air bubble with a volume of ≤80% of the anterior chamber.

Key Words: Descemet membrane endothelial keratoplasty, intraocular pressure, pupillary block, peripheral iridectomy, air bubble

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From the Centre for Ophthalmology, University of Tübingen, Tübingen, Germany.
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Reprints: Tobias Röck, MD, Centre for Ophthalmology, University of Tübingen, Schleichstrasse 12, D-72076 Tübingen, Germany (e-mail: tobias.roeck@med.uni-tuebingen.de).

Descemet membrane endothelial keratoplasty (DMEK) has become a well-established alternative to penetrating keratoplasty (PK) for the treatment of corneal endothelial dysfunction.[1–3]

This new surgical procedure offers several advantages over PK based on its minimal invasiveness and minimal refractive changes with rapid visual recovery.[4–6]

Although there are many advantages, intraocular complications can also occur. In addition to the risk of graft detachment, increased intraocular pressure (IOP) may be one further severe complication after DMEK, especially specific types of glaucoma induced by the presence of an intraocular air bubble in the immediate postoperative phase.[7]

Melles et al[8] introduced a method to fix the donor tissue without sutures on the recipient cornea. Nevertheless, to obtain graft adherence to the recipient posterior stroma, an air bubble in the anterior chamber is needed. Especially grafts without stroma have the most trouble with sticking initially, because the edges tend to curl and push away from the host. For this reason, DMEK grafts require long air bubble support to generate enough suction for a strong bond. This can increase the risk of air bubble-associated IOP elevation after DMEK.

The increased risk of pupillary block after injection of air within the anterior chamber has been well documented in the past.[9–12]

Development of an uncontrolled IOP elevation after penetrating keratoplasty is a well-recognized risk factor for graft failure, endothelial cell loss, and poor visual outcomes and affects the clinical outcome and/or graft survival in the long term.[13–15]

In this study, we retrospectively evaluated the postoperative IOP changes after our first 306 DMEK cases and assessed the occurrence of immediate postoperative IOP elevations because of a retained air bubble.

The aims of our study were to report the incidence and risk factors for pupillary block after DMEK, its management, and possible prevention.

MATERIALS AND METHODS

Patients and Determination of IOP

Our study retrospectively reviewed 306 eyes of 224 patients who underwent DMEK for treatment of corneal edema induced by pseudophakic bullous keratopathy (84 eyes) and Fuchs endothelial dystrophy (222 eyes) from

September 2009 through October 2014. Patients were evaluated preoperatively, 1 day, 1 week, 2 weeks, and 4 weeks after surgery and at 3-month intervals thereafter.

An IOP elevation was defined as a spike above 30 mm Hg. IOP was measured by Goldmann applanation tonometry (Haag-Streit, Bern, Switzerland). If possible, the reasons for IOP elevation were identified. For all 306 eyes, preoperative and postoperative slit-lamp examinations and IOP measurements were performed.

This study was approved by the institutional review board of the University of Tübingen and adhered to the tenets of the Declaration of Helsinki.

Donor Preparation

The donor corneoscleral rim was placed on a sterile circular surface and was scored and stained with trypan blue to highlight the scoring mark; thereafter, it was placed in a corneal viewing chamber containing corneal storage solution (Culture Medium I; Biochrom AG, Berlin, Germany). A circular incision with a hockey knife was made. Complete dissection of the DMEK tissue from the corneoscleral rim was achieved by grasping the peripheral free tissue flap using untoothed curvilinear forceps.[16] A spatula was used to lift the trephinated graft off the stromal bed after complete dissection and trephination. The DM was placed in culture medium before the surgery. At surgery, the culture medium was carefully drained and the DMEK roll was thoroughly rinsed with BSS. To open the tissue and create a double roll, direct flow on the top of the tissue with BSS was applied. The tissue was then stained with trypan blue.

Recipient Preparation, Graft Insertion, and Positioning

To reduce the risk of air-associated pupillary block in the first 190 eyes, an intraoperative peripheral iridectomy was performed at the 12-o'clock position. In the other 116 eyes, a peripheral iridectomy was made at the 6-o'clock position. The surgical technique involved the initial placement of 2 paracenteses in the 2-o'clock and 10-o'clock positions.

A 23-gauge vitreous cutter was inserted into the anterior chamber with the port facing downward, and peripheral iridectomy was performed. The opening had to be sufficiently large (approximately 2 mm in diameter) and as peripheral as possible.

To remove the recipients' DM, proper visualization of the anterior chamber using air pressurized at 30 mm Hg is needed. This is followed by the introduction of a reversed Sinskey hook through a paracentesis for Descemetorhexis. A 2.75-mm clear corneal tunnel was created with a 2.75-mm slit knife at the 12-o'clock position. The dissected donor DM was loaded into a glass shooter in the double-roll form. The injector was turned so that the roll was facing upward. Implantation took place into a soft eye. For confirmation of orientation of the DM, we primarily used Melles rule of the rolled edges with the endothelium facing outward. No air was injected above or below the DM (to aid in the process of unfolding). The eye was kept in the soft state, and digital pressure was applied at the equatorial plane, thereby preventing any refolding or recurling. Apposition and centration was achieved because of the shallow anterior chamber, the soft eye status, and the corneal tapping in combination with equatorial digital pressurization. After complete unfolding, air was (continued to be) injected below the DM via a 30-gauge cannula for final DM fixation.[17] The anterior chamber was filled with air so that you can see a circular meniscus of fluid in the supine position.

Postoperative Management

Postoperatively, patients stayed overnight and a day after operation in a supine position with only bathroom privileges. The standard postoperative medication included topical 0.5% moxifloxacin hydrochloride ophthalmic solution (Vigamox; Alcon Pharma GmbH, Freiburg, Germany), prednisolone acetate 1% (Dexa EDO; Dr. Gerhard Mann GmbH, Berlin, Germany), and hypertonic solution (5% NaCl; University Pharmacy, Tübingen, Germany) 5 times a day. Over a period of 3 to 4 months the prednisolone acetate was tapered down to once daily.

Statistical Analysis

The statistical analysis of the results was performed using *t* tests. Differences between groups were assessed by a Mann–Whitney *U* test. Statistical analysis was conducted using Statistical Packages for the Social Science (SPSS, version 18.0). Quantitative variables were expressed as mean ± standard deviation. $P < 0.05$ was considered statistically significant.

RESULTS

Of the 306 consecutive DMEK cases, 222 were performed for Fuchs endothelial dystrophy and 84 for pseudophakic bullous keratopathy. Of the 306 DMEK cases, 270 were DMEK alone and 36 had DMEK combined with phacoemulsification and intraocular lens (IOL) implantation (triple DMEK). Five eyes were phakic when DMEK was performed. The mean ± standard deviation age at the time of DMEK of all 306 cases was 70.8 ± 10.2 years (range, 36–98 years). The mean age of the 276 cases without IOP elevation was 70.6 ± 10.4 years and of the 30 cases with IOP elevation was 71.9 ± 7.6 years (range, 56–84 years).

Postoperative IOP elevation after DMEK was found in 30 eyes (9.8%) of 27 patients, 17 female and 10 male, aged 56 to 84 years. All eyes presented a de novo IOP elevation within 1 day after DMEK.

The postoperative IOP elevation within 1 day was 15.8% (30 eyes) for the group of eyes with iridectomy at the 12-o'clock position and 0% for the group with iridectomy at the 6-o'clock position, respectively ($P < 0.001$) (see Table, Supplemental Digital Content 1, http://links.lww.com/ICO/A423).

In the patients, an increase in IOP within 1 day after DMEK could be attributed to the air in the anterior chamber.

All 30 eyes had an IOP >30 mm Hg postoperatively because of pupillary block. The IOP ranged from 36 to 70 mm Hg.

Twenty-five of these 30 eyes developed a pupillary block from air anterior to iris and in 5 eyes it was because of angle closure from air migration posterior to the iris.

In 9 eyes, the (posterior) pupillary block was caused because of a total air fill of the anterior chamber. The air bubble pressed the iris against the lens and blocked the aqueous flow (Fig. 1A). Sixteen eyes presented a combination of an anterior and posterior pupillary block caused by an air bubble in the anterior chamber (Figs. 2A, B). The other 7 eyes had a pupillary block because of air behind the iris (Figs. 3A, B).

The incidence of air bubble–induced IOP elevation after DMEK was 9.4% (25/265) in the group with pseudophakic IOL status and 13.9% (5/36) in the triple DMEK group ($P = 0.4$). Two of 5 phakic eyes (40%) developed an air bubble–induced IOP elevation ($P = 0.0475$).

Fourteen of 30 patients could be managed well medically with intravenous acetazolamide, pupillary dilatation, and making the patient strictly lie down in the supine position. The other 16 patients needed a partial air removal at the slit lamp.

Of the 30 eyes with increased IOP after DMEK, 26 eyes allowed for best-corrected visual acuity measurements at the 6-month follow-up interval. In the 4 remaining eyes, secondary graft failures were seen. Twenty-three of these eyes (88.5%) reached a best-corrected visual acuity of ≥20/40 (≥0.5), 9 eyes (34.6%) reached ≥20/25 (≥0.8), and 4 eyes (15.4%) reached ≥20/20 (≥1.0).

DISCUSSION

An iatrogenic increase of IOP after DMEK is a serious complication. Especially, air bubble–induced angle closure is attributed to the operative technique, which entails the injection of an air bubble into the anterior chamber to tamponade the graft to the recipient cornea. The increase in IOP caused by air in the anterior chamber has been well reported in the past.[9–12] and has been previously described in DSEK patients.[18–20] Lee et al described in 7 of 100 eyes a secondary angle closure caused by air after DSEK. In phakic DSEK patients, the incidence of air bubble–induced pupillary block was even higher with 3 of 10 eyes.[21] Mechanisms leading to pupillary block in DSEK and DMEK have to be the same. For this reason, the risk for pupillary block must be very similar in DMEK and DSEK. In both cases, a complete air fill of the anterior chamber can lead to a pupillary block. But because of the fact that DMEK grafts without stroma require longer air bubble support in contrast to DSEK grafts and DMEK has a relatively higher rebubbling rate than DSEK (7%–20% vs. 33%–81%), higher risk of pupillary block can be induced.[22,23] In our experience, DMEK surgeons leave a large and full air bubble after DMEK. Ćirković et al[24] showed that larger air bubbles in the anterior chamber decrease the risk of graft detachment after DMEK and reduce the rebubbling rate.

Melles et al still experienced a 30% dislocation rate when they did not leave any residual bubble.[25–27] Maier et al[28] showed, in accordance with our results, postoperative angle-closure

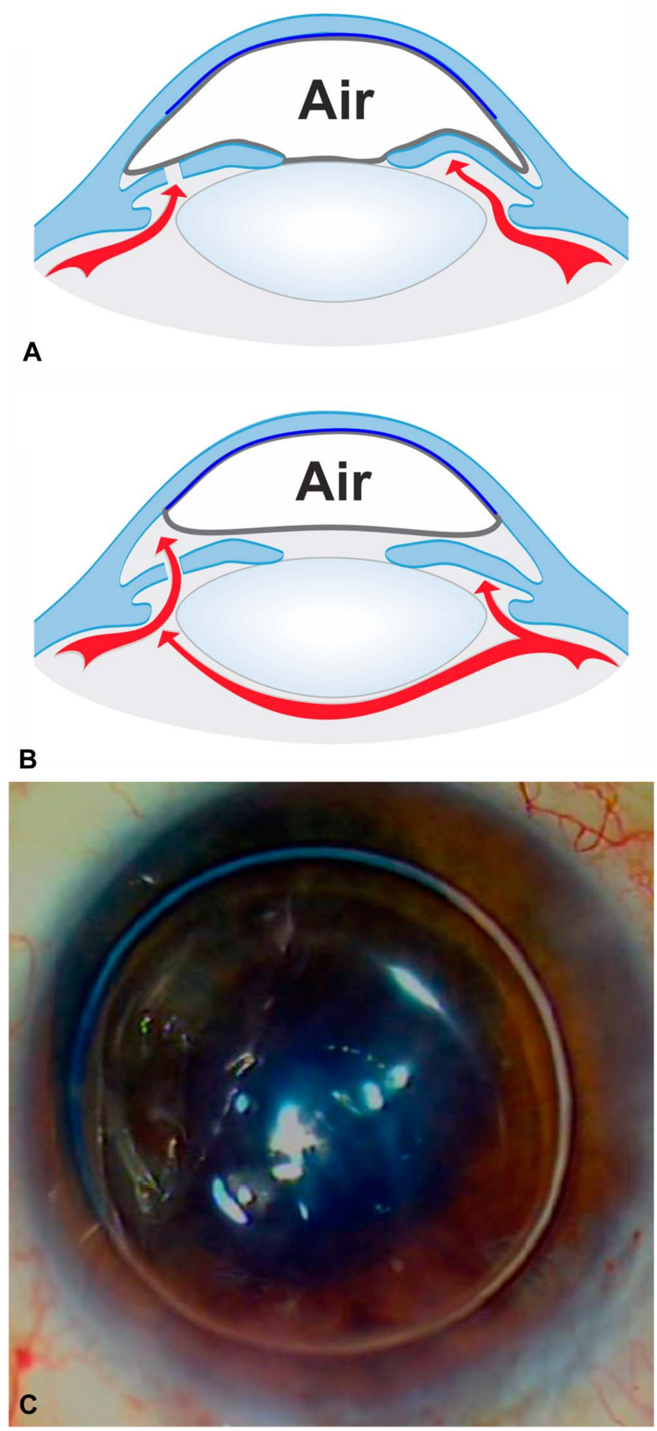

FIGURE 1. Graphic example and photograph of total air fill and ≤80% of air in the anterior chamber. A, A total air fill of the anterior chamber presses the iris against the lens and blocks the aqueous flow. B and C, To prevent this kind of pupillary block, the anterior chamber should be filled with ≤80% of air. This leaves a 360-degree fluid meniscus in a supine position over a sufficient peripheral iridectomy to allow aqueous flow and circumvent pupillary block.

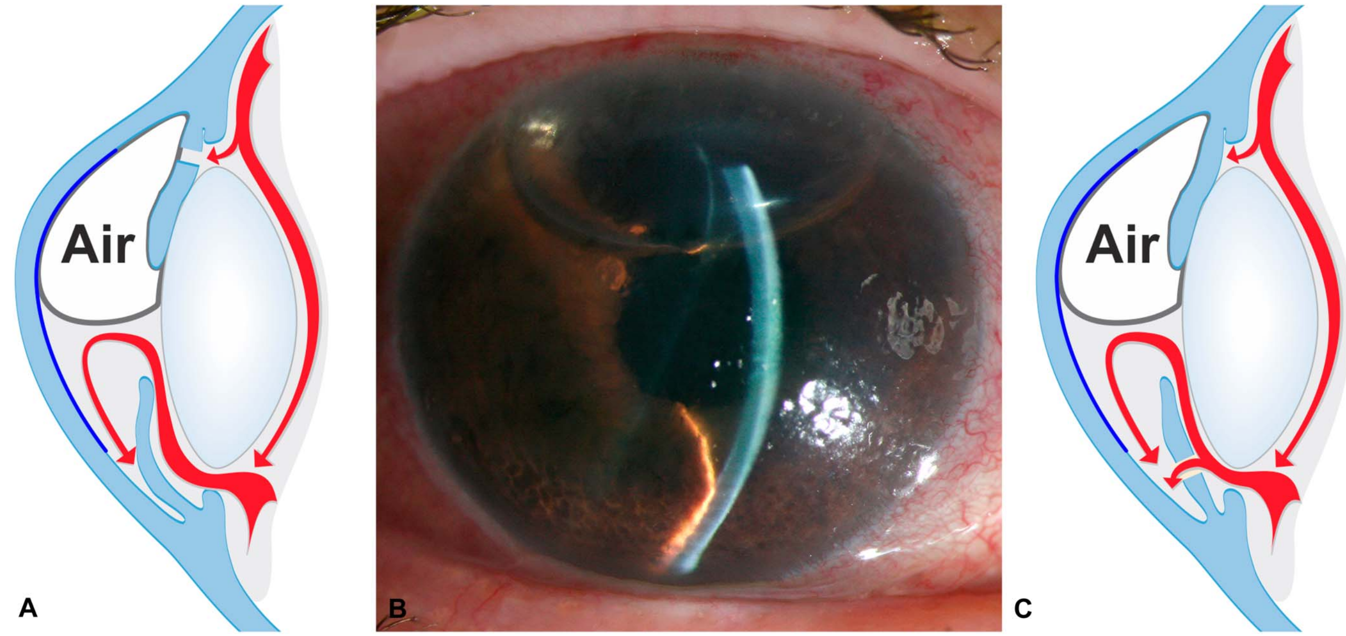

FIGURE 2. Graphic example and photograph of a combination of anterior (inferior) and posterior (superior) pupillary blocks. A and B, If the patient is sitting upright, air can cause a combination of anterior (inferior) and posterior (superior) pupillary blocks. C, This kind of pupillary block can be prevented with an inferior peripheral iridectomy.

glaucoma in 15.4% of patients who underwent DMEK within the first 24 hours postoperatively.

In our series, postoperative IOP elevation after DMEK was found in 30 of 306 eyes. In these cases, the air bubble caused different kinds of pupillary block (Figs. 1–3).

In 9 eyes, the (posterior) pupillary block was caused because of a complete air fill of the anterior chamber (Fig. 1A). The air bubble presses the iris against the lens, blocking the flow of aqueous through the pupil and out of the trabecular meshwork. The trapped aqueous elevates the peripheral iris in a bombe configuration for a full 360 degree if the patient is lying in the supine position. Removing excess air can restore the circulation faster. To prevent this kind of pupillary block, we filled the anterior chamber with an air bubble with a volume of ≤80% (Fig. 1C). This leaves a 360-degree fluid meniscus in a supine position over a sufficient peripheral iridectomy to allow aqueous flow and circumvent pupillary block (Fig. 1B).

Sixteen eyes presented a combination of an anterior and posterior pupillary block caused by an air bubble in the anterior chamber (Figs. 2A, B). The inferior part of the iris is displaced forward, and this leads to a mechanical closure of

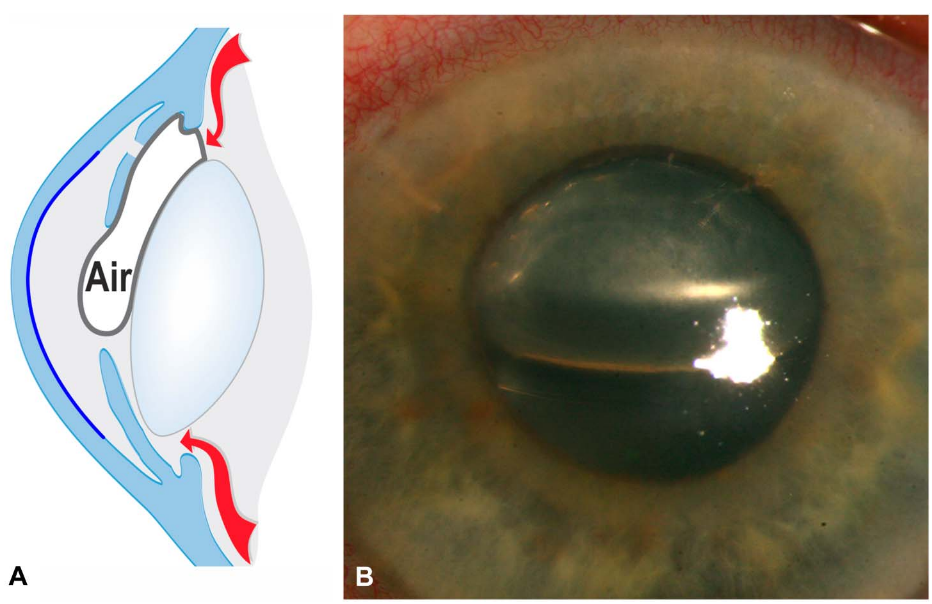

FIGURE 3. Graphic example and photograph of a pupillary block caused by an angle closure from air migration posterior to the iris. A and B, Pupillary block caused by an angle closure from air migration posterior to the iris. This results in an anterior displacement of the iris with irido-corneal touch and angle closure.

the anterior chamber angle. All the eyes had an iridectomy at the 12-o'clock position. This kind of pupillary block can be prevented with an inferior peripheral iridectomy (Fig. 2C).

The other 5 eyes had pupillary block because of angle closure from air migration posterior to the iris (Fig. 3). This results in anterior displacement of the iris with iridocorneal touch and angle closure.

We found that patients undergoing DMEK combined with cataract surgery and IOL implantation are at a higher risk for pressure spikes. The reason could be that in newly pseudophakic eyes, a flexible IOL–iris diaphragm allows for more air to be pumped into the anterior chamber. Also, floppy iris could be another risk factor for pupillary block. The anatomical features of the anterior chamber may also increase the risk of air bubble–induced IOP elevation. Floppy iris can lead to air migration posterior to the iris and can cause anterior displacement of the iris with iridocorneal touch and angle closure. In our study, the 10 male subjects with an increase in IOP had no medical history of α_1-adrenergic receptor antagonists such as Tamsulosin.

The angle-opening distance, the anterior chamber depth, and pupil diameter could be predictive factors.

Only 5 eyes were phakic in our study, so in a relatively high incidence of 40% (2/5), an air bubble–induced IOP elevation occurred. We realize that it is difficult to draw conclusions from these data because the sample size is small. However, the literature has also reported higher incidences of elevated IOP in phakic patients.[21]

Phakic eyes especially, which are representative of a younger age group, appear to be at a higher risk for pupillary block. For this reason, there should be a good balance between a smaller air bubble at the end of DMEK and the risk for graft detachment to reduce the risk for pupillary block.

In conclusion, our study indicated that eyes undergoing DMEK may require close monitoring of immediate post-operative IOP elevation to detect postoperative air bubble–induced pupillary block. To reduce the risk for IOP elevation because of the residual intraoperative air bubble, an inferior peripheral iridectomy and an air bubble with a volume ≤80% of the anterior chamber volume should be necessary. With prompt and appropriate intervention, IOP can be controlled after DMEK and good visual acuity can be achieved.

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