

GAS BUBBLES AND ALTITUDE



"Classical Gas" meets "Rocky Mountain High" and "Leaving on a Jet Plane."

BY BRIAN C. JOONDEPH, MD, MPS

Three songs from the 1960s and '70s. One is about the wonders of nature in the majestic Rocky Mountains, another an instrumental rock tune, and the third a ballad about going off to the Vietnam War. What do these songs have to do with gas bubbles in the eye?

As a retina surgeon in Denver, I introduce the classic gas bubble to the Rocky Mountains on a regular basis. This situation is not unique to Colorado; it occurs in every state that has mountains. Although other mountain ranges may not be quite as towering as the Rockies, they are certainly high enough to pose a danger to gas-filled eyes.

ADDRESSING ALTITUDE ISSUES

How do we address these altitude issues? The mountain issue may not be relevant to retina surgeons in much of the country, but air travel is ubiquitous and an issue for patients everywhere who are leaving for somewhere on a jet plane.

In this article, I share thoughts, tips, and tricks on this topic with the retina community at large because these issues are not unique to Colorado.

For those who have forgotten their high school and college chemistry, allow me to refresh your memories. Remember Boyle's law? In simple terms, pressure and volume are inversely proportional in relation to gas. As the pressure on a gas bubble decreases, its volume increases. Higher altitude means lower atmospheric pressure and a bigger gas bubble.

Without delving too deeply into

the weeds of physics and chemistry, here are a few simple numbers. A gas or air bubble at sea level will expand by 1.25 times at 5,000 feet, 1.5 times at 10,000 feet, and 2 times at 18,000 feet.¹

Only mountain climbers need concern themselves with elevations of 18,000 feet or more. The highest paved road in the United States is the one leading to the top of Mount Evans in Colorado, at 14,130 feet. The highest US interstate highway pass is the Eisenhower Tunnel along I-70 in Colorado, at 11,158 feet. From Denver, the Mile-High City at 5,280 feet, there is a 6,000-foot elevation change that can happen in less than an hour driving west on I-70, with a resulting 25% to 30% increase in bubble size in a patient with intraocular gas.

A number of other states also have mountain passes over 5,000 feet.² Hence the concern. With good outflow, an eye can tolerate these changes in altitude without a problem. But in other eyes, particularly the eyes we

operate on, this may not be the case.

Researchers in Mexico City, using a rabbit model of intraocular gas and mountain travel, estimated an increase of 1.5 to 2.0 mm Hg in pressure in human eyes for every 100 m of altitude increase.³ That is about a 5 mm Hg increase per 1,000 feet.

After takeoff, commercial airplanes achieve cabin pressure at cruising altitude equivalent to the pressure at 6,000 to 8,000 feet elevation within 10 to 15 minutes.⁴ At this rate, a gas bubble in an eye taking off from sea level would be 30% to 40% larger within minutes.

RECOMMENDATIONS

Let's leave the science behind and get down to practicalities. What should we recommend for patients who need an air or gas bubble and also need to travel into areas of high altitude or by air?

For patients visiting Colorado, or anywhere else for that matter, there is

AT A GLANCE

- ▶ It is important to consider patient travel plans and situations before inserting a gas bubble after vitrectomy.
- ▶ Silicone oil is an option for patients who cannot avoid air travel before a gas bubble would have time to dissipate.
- ▶ Know your local geography so that you can warn patients of potential trouble spots.

always the option of returning home for their surgery rather than having it where they are visiting, avoiding the issue altogether. Obviously, this depends on surgical urgency, the logistics of returning home, and where home is. It's much easier to get a flight from Denver to Chicago than from Bangkok to New York.

Another option is to use silicone oil instead of gas or air. Patients are free to fly with silicone in situ, but this involves the tradeoff of requiring a second surgery in the future to remove the oil. For someone who has just begun a family ski vacation in Colorado and who presents with a retinal detachment, oil is a good option. The patient can stay with his family while on vacation and return home with them, rather than staying in Denver while the family is off skiing and then having to drive home to avoid air travel.

For a patient with a gas bubble in his or her eye, how soon can she fly or travel through the mountains? This is a more challenging question.

For complete safety, one should not change altitude with any gas in the eye. Then again, for complete safety, one should neither fly nor drive in the mountains. But that's not practical.

Elective travel can be delayed until the bubble is completely gone, but what about those who can't delay travel?

For airplane travel, the answer is easy. No flying until the bubble is gone, without exception. Even a small bubble may expand enough for a dangerous IOP elevation, particularly in an eye with impaired outflow. One can turn around on the interstate and get to a lower elevation, but it's not so easy on a plane, particularly over the ocean. Why risk it?

A patient with a small bubble flying out of Denver may get away with it because cabin pressure is within a couple of thousand feet of the airport's elevation. But what if the unforeseen happens? A plane may be diverted to an airport at sea level, causing temporary bubble expansion, then take off again shortly thereafter and go from sea level to 8,000 feet cabin pressure in a few minutes. In such a case, the bubble becomes a big problem.

Airlines generally respond favorably to a note from the doctor explaining why the passenger can't fly and needs the fare refunded or the trip rescheduled.

DRIVING TO HIGHER ALTITUDES

What about driving? Not just from Denver, but from Phoenix, Los Angeles, Salt Lake City, and other cities near mountain passes.

Climbing slowly enough, any elevation change is tolerable because the eye will equilibrate. But by slowly I mean walking, not driving. Again, not practical.

I prefer to wait until the bubble is 50% volume or less before allowing patients to drive to higher altitudes. I give the patient 500 mg oral acetazolamide (Diamox, Teva Pharmaceuticals), assuming no contraindications, to take about an hour before travel, to lower IOP and provide a cushion of safety. I also advise patients to use either their car's navigation system or a smartphone app to determine elevation. There is a free app called My Altitude, and I'm sure there are others.

I instruct patients to pull over for 10 to 15 minutes after each 500-foot elevation gain, giving time to equilibrate to an

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expected 2 to 4 mm Hg IOP rise. Going downhill, they can literally fly, watching for police traps rather than their altitude, because the bubble will shrink during descent.

It's also important to educate patients about the symptoms of elevated IOP, such as pain, pressure, and decreased vision. Tell patients that, in the event of such symptoms occurring, they should turn around, go downhill until the symptoms subside, wait for half an hour, and try the ascent again, but more slowly.

WAIT FOR 50%

The waiting period for a 50% bubble is the hard part for many patients. I use SF₆ routinely—never C₃F₈—so the wait is only about 1 week. The wait would be much longer with C₃F₈. Air, if it will provide adequate tamponade, is another option with a shorter waiting period.

Playing with the percentage of bubble fill at the end of surgery or adjusting the gas concentration are other ways to get to a 50% bubble sooner. However, fixing the eye is the priority. Do not shortchange the tamponade and end up needing another surgery.

Pneumatic retinopexy is another shortcut in appropriate patients. A small amount of pure gas combined with oral acetazolamide, as noted above, will usually be safe for mountain travel, but it is not safe for air travel.

KNOW YOUR GEOGRAPHY

Finally, know your geography and potential trouble spots. State departments of transportation publish pass elevations,⁵ and knowing local quirks can be helpful. For example, in Denver, I-25 runs north to south. There is a large hill on the trip south to Colorado Springs and another heading north, entering Wyoming. Both could cause problems in an eye with a complete gas fill. Know your local hazard spots.

I hope this article has provided some insights into dealing with the “Classical Gas” bubble meeting the “Rocky Mountain High” or “Leaving on a Jet Plane.” ■

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BRIAN C. JOONDEPH, MD, MPS

- Partner, Colorado Retina Associates, Denver, Colorado
- Clinical Professor of Ophthalmology at Rocky Vista University College of Osteopathic Medicine in Parker, Colorado
- bjoondeph@retinacolorado.com; Twitter: @retinaldoctor
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