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Key words: VER, transscleral, normals, stimulus delivery, adaptation

REFERENCES


The relationship between the volume of an intraocular gas bubble and the area of retina covered by the bubble was studied with the use of both a transparent model and a mathematical model of the vitreous cavity. The arc of contact of intraocular bubbles was calculated for vitreous cavities of various diameters. A 0.28 cm³ bubble will cover 90 degrees of retina and be of sufficient size to manage many of the problems for which an internal retinal tamponade would be useful. Larger retinal tears require disproportionately large increases in bubble volume to achieve modest increases in the area of retina covered. Estimating bubble size by observing the height of the bubble meniscus in the dilated pupil is subject to errors induced by small shifts in the angle of observation. A correct evaluation requires that the plane of observation be adjusted so that it coincides with the plane of the meniscus.

In 1938, Rosengren¹ of Sweden described a technique for the treatment of retinal detachments that used a bubble of air to tamponade the retinal break against the pigment epithelium. The operation was displaced by the advent of scleral buckling in the next decade. The introduction of sulfur hexafluoride and other long-lasting gases has renewed interest in the use of intraocular gas bubbles for the management of selected retinal detachments.²⁻⁵ The ability of any gas to act as an effective internal retinal tamponade depends on having sufficient volume to cover the area of the retinal break. Thus it would be of value to know the relationship between bubble volume and the area of retina covered by the bubble. The present communication is intended to delineate this relationship.

Method. A glass model of the vitreous cavity was constructed with an internal diameter of 21 mm and a volume of 4.8 cm³ reflecting the dimensions and volume of the average vitreous cavity. The sphere was filled with water and other fluids. Gas bubbles of measured volume were inserted. The shape of the resultant bubble was observed with parallax controlled, and the angular extent of its arc of contact, designated ϑ, measured (Fig. 1). When it became apparent that for clinically useful

\[ \text{Mechanical properties of intraocular gas} \]

\[ \theta = \text{Degrees of arc of bubble-sphere interface} \]

\[ h = \text{Height of meniscus} \]

Fig. 1. Arc of bubble-retina contact (Θ) and bubble depth (h).

Table I. Relationship of bubble volume to angular extent (Θ) and bubble depth (h) in a vitreous cavity of 21 mm diameter

<table>
<thead>
<tr>
<th>Bubble volume (cm³)</th>
<th>Arc of bubble-retina contact (degrees)</th>
<th>Height of bubble (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25</td>
<td>88</td>
<td>2.9</td>
</tr>
<tr>
<td>0.50</td>
<td>106</td>
<td>4.2</td>
</tr>
<tr>
<td>1.00</td>
<td>132</td>
<td>6.1</td>
</tr>
<tr>
<td>2.00</td>
<td>198</td>
<td>9.1</td>
</tr>
<tr>
<td>2.40</td>
<td>180</td>
<td>10.5</td>
</tr>
</tbody>
</table>
Fig. 2. How changes in the angle of observation can produce shifts in the level of the bubble meniscus in the pupil. A, Bubble viewed at the plane of the meniscus. B, Bubble observed slightly below the plane of the meniscus.

Table II. Relationship of bubble volume to angular extent (θ) for vitreous cavities of various diameters from 19 to 24 mm

<table>
<thead>
<tr>
<th>Arc of bubble-retina contact (degrees)</th>
<th>19 mm</th>
<th>20 mm</th>
<th>21 mm</th>
<th>22 mm</th>
<th>23 mm</th>
<th>24 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>0.2080</td>
<td>0.2430</td>
<td>0.2800</td>
<td>0.3200</td>
<td>0.3690</td>
<td>0.4200</td>
</tr>
<tr>
<td>120</td>
<td>0.5620</td>
<td>0.6560</td>
<td>0.7500</td>
<td>0.8700</td>
<td>0.9900</td>
<td>1.1300</td>
</tr>
<tr>
<td>150</td>
<td>1.1100</td>
<td>1.3000</td>
<td>1.4900</td>
<td>1.7300</td>
<td>1.9700</td>
<td>2.2400</td>
</tr>
<tr>
<td>180</td>
<td>1.7980</td>
<td>2.1000</td>
<td>2.4000</td>
<td>2.7900</td>
<td>3.1800</td>
<td>3.6200</td>
</tr>
</tbody>
</table>

volumes the lower edge of the bubble was actually flat, the arc of contact was calculated by means of an equation derived from the standard formula for the volume of a polar cap:

\[ \text{Volume} = \frac{\pi a^3}{3} (2 - 3 \cos \frac{\theta}{2} + \cos^3 \frac{\theta}{2}) \]

where \( a \) = radius of vitreous cavity and \( \theta \) = arc of bubble-retina contact in degrees. Subsequently, the volumes of gas required to produce bubbles of equivalent angular extent were calculated for eyes of various internal diameters.

Results

Effects of various media on gas bubble configuration. There were no observable differences in bubble configuration with (1) air in water, (2) air in donor vitreous, (3) air in silicone oil, or (4) sulfur hexafluoride in water. The base of the bubble, the meniscus, was essentially flat in all preparations.

Angular extent of various volumes of gas measured in the model eye. Table I lists the angular extent of the arc of bubble-retina contact (θ) and bubble depth (h) for bubble volumes of 0.25, 0.5, 1.0, 2.0, and 2.4 cm³ (one-half the vitreous volume) as observed in the model eye.

Volume requirements for eyes of larger diameters. The calculated bubble volumes necessary to produce angular extent \( \theta \) of 90 to 180 degrees, a therapeutic range, in eyes with vitreous cavities of various diameters are listed in Table II. As the diameter of the vitreous cavity increases, there is a corresponding increase in volume to produce bubbles of equivalent angular extent. Going from an average eye with a vitreous cavity diameter of 21 mm to a myopic eye with a vitreous cavity diameter of 24 mm requires an increase in volume of 50% to produce bubbles that cover equivalent areas of retina.

As θ increases from 90 to 120, 150, or 180 degrees, irrespective of the diameter of the vitreous cavity, the volume necessary to produce these changes is equal to the volume for a 90-degree bubble multiplied by a factor of 2.7, 5.3, and 8.6, respectively.

Effects of the angle of observation on the height
of the bubble meniscus. Fig. 2 illustrates a 1.0 cm³ bubble viewed at the plane of the meniscus. In this position the meniscus appears as a thin dark line with minimal curve just visible in the pupillary aperture. If the angle of observation is lowered, less than 5 degrees, one sees progressively more of the base of the bubble (Fig. 2). Viewed through the pupil, the meniscus now has an elliptical shape, making the bubble appear to fill the superior third of the pupil, simulating a 2.0 cm³ bubble.

Discussion. With the use of a transparent model to demonstrate the configuration of gas bubbles in the vitreous cavity and a mathematical model to calculate bubble volumes, it is clear that small volumes of gas produce large arcs of bubble-retina contact. When this is applied to retinal detachment surgery, it becomes apparent that a great number of the problems for which an intraocular tamponade would be useful could be managed with relatively small quantities of gas. For example, in the average eye a 0.28 cm³ bubble will cover a 90-degree area of retina and be sufficient to press out undesirable folds in the retina, manage a fish-mouthing retinal hole, or simply tamponade a retinal break that is not responding to scleral buckling. Larger tears require disproportionately large increments in volume. A 90-degree tear would be just covered by a 0.28 cm³ bubble. To cover a 180-degree tear would require a 3.3 cm³ bubble. To obtain a minimal overlap of 15 degrees to either side of the tear would necessitate a further increase in volume to 3.3 cm³, over two thirds of the entire vitreous cavity volume.

Estimating residual bubble size in the patient is clinically useful. Observations in the model eye have shown that small shifts in the angle of observation can produce significant changes in the level of the bubble meniscus. A 1.0 cm³ bubble can be made to simulate a 2.0 cm³ bubble simply by changing one’s angle of observation (Fig. 2). A correct evaluation of intraocular bubble size requires that the plane of observation be adjusted so that it coincides with the plane of the meniscus. Practically, this is obtained by adjusting one’s level of observation to the point where the meniscus is a thin dark line with minimal curve.


Key words: intraocular gas, retinal detachments, intraocular gas tamponade, estimating intraocular bubble size, retinal tamponade, intraocular volume-area relationship

REFERENCES


The fine structure of nuclear changes in superior limbic keratoconjunctivitis. H. BARRY COLLIN, PETER C. DONSHIK, S. ARTHUR BORUCHOFF, C. STEPHEN FOSTER, AND H. DWIGHT CAVANACH.

Superior limbic keratoconjunctivitis (SLK) is a condition of unknown etiology. Histological signs include acanthosis, dyskeratosis, keratinization, and balloon degeneration of the bulbar conjunctival epithelium. Ultrastructural examination of biopsy material from five eyes of patients with SLK shows numerous nuclear changes in the conjunctival epithelial cells. These include abnormal distribution and aggregation of nuclear chromatin, the presence of filaments within the nucleus, and dense accumulations of cytoplasmic filaments which surround the nucleus, resulting in "strangulation" and the formation of multilobed nuclei or multinucleated cells. These changes do not appear to have been described previously in any cell type.

The clinical1-2 and histological3-4 characteristics of superior limbic keratoconjunctivitis (SLK) in man have been reported. However, there is only one report of the ultrastructural features which accompany this condition3 and in that publication the changes in the nuclei of the bulbar conjunctival epithelial cells were not described. Apart from the degenerative changes there was brief reference only to abnormal chromatin distribution and tortuosity of the nuclear envelope.

In this study, unusual ultrastructural appear-