Priming the Ahmed Glaucoma Valve: Pressure Required and Effect of Overpriming

Jason Cheng, MBBS, FRCOphth, FEBO, Milad Abolhasani, BSc, MASc,† Laura Beltran-Agullo, MD,‡ Edward Bram Moss, MD,§ Yvonne M. Buys, MD, FRCSC,§ and Graham E. Trope, MD, PhD, FRCSC§*

Purpose: To determine the pressure required to prime an Ahmed Glaucoma Valve (AGV) and determine whether the valve can be damaged by "over-priming pressure."

Methods: Three AGVs, a syringe pump, and a manometer were used to assess priming pressure. Balanced salt solution was pumped through the AGV tube at increasing pressures until a jet of fluid was seen to eject from the AGV, as per manufacturer instructions. This was repeated 3 times for 3 different virgin AGVs giving the "priming pressure." A second experiment used the same experimental set up to determine the "over-priming pressure" on 3 other AGVs. Fluid was pumped through the AGV at increasing pressures until evidence of damage was seen. The valve function was assessed before and after the "over-priming" stress test. Valve function was determined by the closing pressure, which is the pressure at which the valve closes and fluid was no longer seen passing through the valve.

Results: The priming pressure in the 3 AGVs was 2844, 3154, and 3051 mm Hg (mean, 3017 ± 158 mm Hg). The maximum pressure generated using the syringe pump was 10,860, 10,343, and 10,860 mm Hg (mean, 10,688 ± 299 mm Hg). No damage was observed in the valve mechanism. AGV closing pressure before the "over-priming" stress test was 8, 6, and 13 mm Hg and after the stress test was 6, 7, and 13 mm Hg.

Conclusion: This study demonstrates that the priming pressure is consistent at around 3000 mm Hg. In addition, over-priming is not likely to damage or disturb the closing pressure.

Key Words: glaucoma, Ahmed glaucoma valve, glaucoma drainage device, priming, priming pressure, overpriming

(*J Glaucoma* 2014;00:000–000)

It has been postulated that excessive force during priming, termed "overpriming," may damage the valve leaflets in the Ahmed glaucoma valve (AGV; New World Medical, Ranchos Cucamonga, CA) and in turn increase the risk of hypotony in the immediate postoperative period.[1,2] Our hypothesis was that the AGV mechanism cannot be damaged by the priming process, that is, be "overprimed." We also experimentally investigate the pressure required to prime the AGV (priming pressure).

METHODS

Two experiments were performed, the first to measure priming pressure and the second to measure effects of overpriming. Three virgin AGV's were used in each experiment (6 in total). The same AGV was not used in both the experiments.

The first experiment used a syringe pump (high-pressure OEM syringe pump module; Harvard Apparatus, MA) with a 20 mL luer lock plastic syringe (Becton; Dickinson and Company, Mississauga, ON, Canada) attached to a fluid manometer (30, 100, and 1000 psi; SSI Technologies Inc., Janesville, WI) and an AGV, via a 3-way stop cock (Fig. 1). The syringe pump delivered fluid at different specified flow rates to generate and adjust the pressure applied on the AGV. The pressure required to generate a jet of fluid through the AGV was recorded in 3 separate virgin AGVs.

The second experiment consisted of 3 parts. The first part was to assess the open and closing pressure of 3 AGVs after routine priming. This was followed by efforts to overprime the AGV with maximal possible pressure followed by reassessment of the opening and closing pressure of the AGVs.

After initial priming, open and closing pressures were measured using a liquid column manometer attached to a bag of balanced salt solution (BSS) and AGV via a 3-way stop cock. This technique has been previously described.[3,4] In brief, the pressure was measured from the liquid column in cm H_2O. The pressure was altered by adjusting the BSS bag height. The bag height was raised until fluid started seeping through the valve and then lowered until fluid stopped. This pressure was termed opening and closing pressure, respectively. The opening and closing pressure was measured 3 times in 3 different AGVs.

The overpriming experiment was performed using the initial set up described above (Fig. 1). The syringe pump was set to a flow rate of 20 mL/min. Pressure was then allowed to continually increase until evidence of disruption was observed. We were unable to use a 1- or 3-mL syringe

FIGURE 1. Schematic of the experimental set up.

Received for publication September 24, 2013; accepted July 23, 2014.
From the *Khoo Teck Puat Hospital, Singapore, Singapore; †Mechanical and Industrial Engineering Department; §Department of Ophthalmology, University of Toronto[5]and Department of Ophthalmology, Toronto Western Hospital, Toronto, ON, Canada; and ‡Institut Català de la Retina, Barcelona, Spain.
Six Ahmed glaucoma valves were provided by New World Medical, Ranchos Cucamonga, CA.
Disclosure: The authors declare no conflict of interest.
Reprints: Jason Cheng, MBBS, FRCOphth, FEBO, Department of ophthalmology and visual sciences, Khoo Teck Puat Hospital, 90 Yishun Central, Singapore, 768828 (e-mail: jdcheng@gmail.com).

DOI: 10.1097/IJG.0000000000000099

as recommended by the manufacturer because of the low volume relative to the dead space volume of our set up. Because a 1-mL syringe generates higher pressure than a 20-mL syringe due to the smaller plunger surface area (pressure = force/area), we also assessed the "maximum hand pressure" using a BSS-filled 1- and 3-mL syringe attached directly to a pressure gauge to determine the maximum pressure that can be generated by hand. This was performed by 2 male volunteers, using their dominant hand and repeated 3 times.

RESULTS

The priming pressure in the virgin AGVs was 55 psi (2844 mm Hg), 61 psi (3154 mm Hg), and 59 psi (3051 mm Hg) (mean, 3013 mm Hg; SD = 158 mm Hg). No visible damage to the AGV or the connecting system was seen at maximal pressures of 210 psi (10860 mm Hg), 200 psi (10343 mm Hg), and 210 psi (mean, 10688 mm Hg; SD = 299 mm Hg). At these pressure levels the syringe flange buckled and it was not possible to increase the pressure further.

The average opening pressure in each of the 3 AGV's, before the "overpriming" experiment, was 8, 6, and 13 mm Hg. The average closing pressure was 4, 3, and 7 mm Hg, respectively. Following overpriming, the opening pressure was 7.7, 7, and 12.7 mm Hg and the average closing pressure was 4, 3.7, and 7 mm Hg, respectively.

The maximum pressure generated by hand using a 1-mL syringe was 160 psi (8274 mm Hg) and 210 psi (10860 mm Hg), by volunteer 1 and 2, respectively. Maximum pressure generated with the 3-mL syringe was 140 psi (7240 mm Hg) and 155 psi (8016 mm Hg), by volunteer 1 and 2, respectively.

DISCUSSION

The AGV restricts flow through a specially designed, tapered trapezoid chamber that consists of 2 thin silicone elastomer membranes held in a polypropylene body. It is the 2 elastic membranes that restrict flow by changing shape depending on the pressure and flow rate. The manufacturer recommends priming the AGV by injecting 1 mL of BSS into the tube with a 30-G cannula until a vertical jet of fluid is seen. There are several reported reasons for the importance of priming, including breaking the surface tension between the 2 membranes,[2] to ensure the valve opens properly,[5] identify defective AGVs,[6] and to expel the air from the valve chamber.

Our data suggest that the required priming pressure is between 2844 and 3154 mm Hg. The priming process requires a hard push to overcome the initial high resistance. Once the fluid opens the leaflets, the resistance suddenly drops. It has been reported that the high pressure and sudden change in pressure can damage the valve mechanism and it is recommended that care be taken to avoid "overpriming."[1,2,7]

In experiment 2 no disruption to the flow system was observed following overpriming. Damage to the valve may be demonstrated by leakage around the plate. The connection between the 30-G cannula and the AGV tube was also a potential weak point. Previous studies have shown a characteristic variability in the AGV opening and closing pressures which was also seen in our 3 AGVs.[3,4] This work shows any variability is inherent and not caused by the priming process.

We report that the valve function is not damaged by pressures of up to 10860 mm Hg (the maximum attainable with the experimental set up). This pressure level is > 3 times the priming pressure and therefore routine priming is unlikely to damage valve function. At pressures over 10000 mm Hg, a 20-mL syringe begins to buckle and our volunteers were only able to generate this pressure with a 1-mL syringe in a closed system with maximal strength. Routine priming does not reach pressures close to 10000 mm Hg.

Limitations of this study are that we used opening and closing pressure as a measure for in vivo valve function. We did not directly assess if excessively high-pressure priming affects the clinical performance of the AGV in the immediate postoperative phase. We performed this experiment in a small number of valves.

In conclusion, we report that the AGV has a robust leaflet mechanism that can withstand pressures at levels well above those generated during routine priming without influencing subsequent opening and closing pressures. We also report that normal priming pressure is between 55 and 61 psi or 2844 and 3154 mm Hg.

REFERENCES

1. Sarkisian SR Jr. Tube shunt complications and their prevention. *Curr Opin Ophthalmol*. 2009;20:126–130.
2. Ramakrishan R, Krishnadas R, Robin AL, et al. *Diagnosis and Management of Glaucoma: Jaypee Brothers*. New Delhi, India: Medical Publishers; 2013:608–609, 750p.
3. Moss EB, Trope GE. Assessment of closing pressure in silicone Ahmed FP7 glaucoma valves. *J Glaucoma*. 2008;17:489–493.
4. Jones E, Alaghband P, Cheng J, et al. Preimplantation flow testing of ahmed glaucoma valve and the early postoperative clinical outcome. *J Curr Glau Prac*. 2013;1:1–5.
5. Allingham RR, Shields MB, Ovid Technologies Inc. *Shields' Textbook of Glaucoma*. Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins Health; 2011. Available at: http://alias.libraries.psu.edu/eresources/proxy/login?url = http://ovidsp.ovid.com/ovidweb.cgi?T = JS&PAGE = booktext&NEWS = N&DF = bookdb&AN = 01437574/6th_Edition&XPATH = /PG(0).
6. Feldman RM, el-Harazi SM, Villanueva G. Valve membrane adhesion as a cause of Ahmed glaucoma valve failure. *J Glaucoma*. 1997;6:10–12.
7. Albert DM, Lucarelli MJ. *Clinical Atlas of Procedures in Ophthalmic and Oculofacial Surgery*. Oxford, England: Oxford University Press; 2011:384, 1094p.