Experimental anterior chamber maintenance in active versus passive phacoemulsification fluidics systems

C. Manuel Nicoli, MD, Ramon Dimalanta, PhD, Kevin M. Miller, MD

PURPOSE: To evaluate the ability of phacoemulsifiers with active versus passive infusion fluidics control systems to maintain target intraocular pressures (IOPs) under varying flow conditions.

SETTING: Alcon Research, Ltd., Lake Forest, California, USA.

DESIGN: Experimental study.

METHODS: An acrylic test chamber was used to model the anterior chamber of the eye. Two passive (gravity-based) systems were tested using bottle heights yielding infusion pressures of 41, 75, and 109 cm of water under zero-flow conditions. One actively controlled system was tested using equivalent target IOPs of 30, 55, and 80 mm Hg. Test chamber IOPs were measured at aspiration flow rates of 15, 30, 45, and 60 cc/min.

RESULTS: The measured flow rates were similar between fluidics systems across the range of intended aspiration flow rates. All systems achieved the desired target IOPs under zero-flow conditions. After activation of aspiration flow, however, measured IOPs decreased from target IOPs for the 2 passive systems. Each 15 cc/min increase in the aspiration flow rate produced a pressure drop of 14.0 to 16.2 mm Hg or 9.3 to 14.2 mm Hg, depending on the system. Measured IOPs in the actively controlled system closely matched the targeted IOPs across all tested aspiration flow rates, deviating from targets by no more than 4.3 mm Hg.

CONCLUSIONS: All phacoemulsification aspiration infusion fluidics systems achieved target IOPs under zero-flow conditions. Only the actively controlled system maintained target IOPs across a range of aspiration flow rates. These experimental findings suggest that anterior chamber stability might be better in the clinical setting using an actively controlled system.

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Anterior chamber maintenance is one of the keys to successful outcomes in phacoemulsification cataract surgery.[1] One primary factor in maintaining a safe and stable anterior chamber is controlling intraocular pressure (IOP) to stay within or near the physiologic range.[2] However, large fluctuations in IOP can occur during cataract surgery.[3] An IOP that is too high can cause ocular discomfort, decreased ocular perfusion, accelerated glaucomatous optic nerve damage, and postoperative corneal edema.[4,5] An IOP that is too low or that fluctuates widely can lead to instability or collapse of the anterior chamber, ocular discomfort, and trauma to anterior segment structures such as the cornea, iris, and lens capsule.[6]

In passive or gravity-based phacoemulsification aspiration devices, pressure and flow are inversely related; increased flow results in decreased pressure and vice versa, in particular when the source pressure is held constant.[7] During phacoemulsification, inflow supplied by the irrigation line equals outflow under steady-state conditions. Total outflow is the sum of flow through the aspiration line and leakage through the incisions.[8] If incision leakage is zero, the infusion flow rate equals the aspiration flow rate. Because

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intraoperative IOP and the infusion flow or aspiration flow rate are inversely related, compensation for active fluid dynamics is critical if a surgeon desires to achieve and maintain a target IOP during phacoemulsification surgery.

Modern phacoemulsification aspiration systems use advanced aspiration fluidics technologies to control the fluid flow from the eye. As technological developments facilitate increasingly smaller corneal incisions and more efficient application of ultrasound (US) energy, infusion fluidics and anterior chamber stability are becoming increasingly important. Most phacoemulsification aspiration systems control the aspiration of fluid out of the eye using a venturi or a peristaltic pump.[9] The passive force of gravity on the fluid column determines the infusion pressure. The higher the fluid reservoir is positioned above the eye, the higher the IOP, all other factors being equal. The primary limitation of passive or gravity-based fluidics is that IOP varies with the aspiration flow rate; increasing or decreasing the aspiration flow rate results in lower IOP or higher IOP, respectively. The IOP can drop quite low if a high aspiration flow rate (eg, 60 cc/min) is commanded, even if the irrigation bottle or bag is positioned relatively high above the eye.

Some phacoemulsification aspiration systems augment IOP by pressurizing the irrigation bottle with gas. Because the gas infusion pressure does not necessarily vary in response to changing the aspiration flow rate, the effect is the same as raising the irrigation bottle or bag height. One phacoemulsification aspiration system augments IOP control by dynamically squeezing a compliant bag of irrigating fluid in response to the aspiration flow rate and estimated incision leakage. This system differs from traditional gravity-based systems in that it provides active control of infusion pressure to maintain a more stable target IOP level despite variations in the aspiration flow rate.

The objective of this laboratory study was to evaluate the ability of phacoemulsifiers with active and passive infusion fluidics systems to maintain target IOPs.

MATERIALS AND METHODS

Phacoemulsification Aspiration Systems and Fluidics Configurations

The following 2 phacoemulsification aspiration systems were evaluated in this study: the Infiniti Vision System (Alcon Laboratories, Inc.) and the Centurion Vision System (Alcon Laboratories, Inc.). Both use peristaltic pumps to control aspiration. Similar to other gravity-based phacoemulsification aspiration systems, the Infiniti uses a bottle of balanced salt solution suspended by an adjustable pole with gravity supplying the infusion pressure (Figure 1, *A* and *B*). The Centurion can operate in 1 of 2 infusion modes; that is, using gravity as a passive force or using an active system that compresses a compliant, balanced salt solution–filled bag between motorized plates (Figure 1, *C*). The actively controlled system applies or releases bag pressure in response to varying irrigation pressure at the cassette to maintain a target IOP during surgery despite varying aspiration flow rates.

Three phacoemulsification aspiration configurations were tested. The Infiniti was outfitted with an Infiniti Ozil handpiece, Infiniti Intrepid Plus Fluidics Management System (FMS) cassette and tubing, and an Alcon balanced salt solution bottle (configuration 1). The Centurion was tested with passive infusion fluidics (Centurion-gravity; configuration 2) and active infusion fluidics (Centurion-active; configuration 3). In the gravity configuration, the Centurion was outfitted with a Centurion Ozil handpiece, Centurion Gravity FMS, and an Alcon balanced salt solution bottle. In the active configuration, the Centurion was outfitted with a Centurion Ozil handpiece, a Centurion Active FMS, and a Centurion balanced salt solution bag. To minimize variations across experiments, a 45-degree mini-flared Kelman tip (Alcon Laboratories, Inc.) and an Ultra Sleeve (Alcon Laboratories, Inc.) were used for all experiments.

Experimental Setup

The anterior chamber of the eye was modeled using a noncompliant acrylic test chamber. Simulated IOP within the chamber was measured using an electronic pressure transducer (Foxboro, Honeywell), and the aspiration flow rate was measured using a flow probe (ME1PXN Flowprobe, Transonic Systems, Inc.) and a flow meter (TS410 Flowmeter, Transonic Systems, Inc.). The accuracy of the pressure transducer was checked against a separate factory-calibrated digital pressure meter (DPM4 Parameter Tester, Fluke Biomedical) before each experiment. The flow measurement system (flow meter and probe) was calibrated against a syringe pump (Pump 33, Harvard Apparatus) at discrete flow rates of 15 cc/min, 30 cc/min, 45 cc/min, and 60 cc/min. Pressure and flow-rate data were recorded

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Corresponding author: Kevin M. Miller, MD, Edie and Lew Wasserman Building, 2nd Floor, 300 Stein Plaza, UCLA, Los Angeles, California 90095-7000, USA. E-mail: miller@jsei.ucla.edu.