

Achieving High-performance Vitrectomy With Smaller-diameter Systems

The next era of evolution in vitreous cutters will be driven by the quest to increase efficiency, improve safety, expand indications for use, and reduce costs.

BY SOPHIA Y. FANG; JOEL M. CICHELLA; AND MARK S. HUMAYUN, MD, PhD

Optimizing the performance of the ideal vitreous cutter will center on attaining the advantages of small-incision surgery¹ without sacrificing the flow efficiency characteristics of current systems that use larger-diameter instrumentation.^{2,3} The push for greater vitreous removal efficiency in smaller-diameter cutters will be coupled with the development of mechanisms to reduce vitreoretinal traction, thus improving the safety of cutter operation near the retina. Ergonomic advances will aim to reduce the vibration, weight, and form factor of the handpiece to allow greater surgeon control in manipulating the instrument. Alterations in the instrument's design would also expand the efficacy of the vitreous cutter when dealing with surgical challenges beyond vitreous removal, including retinal tears; delamination; membrane manipulation; and removal of other tissues such as blood clots and lens fragments.

THE UNDERLYING PATHWAY TO ACHIEVING IDEAL PERFORMANCE

The development of a better vitreous cutter relies on a fundamental understanding of the various factors that contribute to its ideal performance and the interactions among them. The efficiency of vitreous removal depends upon such factors as port size, internal cutter diameter,

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cut speed, and duty cycle. The internal cross-sectional area of the cutter limits the maximum volume of fluid that can be aspirated per unit time; this is the primary factor responsible for reduced flow efficiency in 25- compared with 20-gauge systems. If the size of the cutter port is optimized, the flow rates that can be achieved with the given internal dimensions can be maximized.⁴

Given these physical constraints, vitreous removal rates can be further optimized by manipulating aspiration pressures, cut speed, and duty cycle. The pulling force that draws the vitreous body into the internal cavity of the cutter is provided by the aspiration pressure, which the surgeon can dynamically control on existing vitrectomy platforms. The evacuation of the vitreous, however, depends on the ability to cut and separate small chunks of vitreous from the greater vitreous body. If all other parameters are held constant, the surgeon can use a higher cut speed, which produces a greater

number of smaller-diameter chunks per unit time. Higher cut speeds allow greater vitreous flow rates,⁵ providing the impetus to develop cutters with greater cut speed capability.^{6,7}

Another significant determinant of vitreous removal is duty cycle (ie, the percentage of time the cutter port is open relative to the complete cutting cycle). The ability to maintain relatively high duty cycles at faster cut speeds correlates with greater vitreous flow rates.^{2,4} Thus, by optimizing duty cycle, faster cut speeds can be used without compromising vitreous flow performance.

Duty cycle and cut speed are dictated by the cutter's drive mechanism. The pneumatic handpieces that dominate today's vitreoretinal market tend to be small and lightweight so that little stress is placed on the surgeon's hand. Despite these ergonomic advantages, the pneumatic drive has inherent limitations. Pneumatic cutters on the market operate with the same paradigm: A single line pulses the air supply that is required to drive the cutter to the closed position. A spring returns the cutter to the open position. The restoring force associated with the spring is fixed. Therefore, the time required for the cutter to open is also fixed—irrespective of the cut speed. The time required for the cutter to close, however, decreases as the cut speed increases. This operating paradigm leads to decreasing duty cycles with higher cut speeds.

The duty cycle of electric cutters remains constant across all cut speeds—whether the cutter is operated at 500, 2,500, or even 10,000 cuts per minute (cpm). Because of recent technological advances, electric cutters are now more comparable in size to current pneumatic cutters. These advances will likely lead to a resurgence of electric cutters.

TECHNOLOGY HEADING TOWARD HIGH-PERFORMANCE

We recently compared the performance of a new-generation, 25-gauge, spring-return pneumatic vitreous cutter (Adaptable Vit Enhancer [AVE]; MID Labs, San Leandro, CA)* with that of current-generation cutters (Accurus and Accurus 2500 cutters; Alcon Laboratories, Inc., Fort Worth, TX) under a clinical vacuum pressure of 500 mm Hg.⁷ The new-generation, 25-gauge pneumatic cutter operates at a maximum speed of 2,500 cpm, exceeding the 1,500 cpm maximum speed of the current-generation, 25-gauge instrument.

In vitro flow rates were measured with extracted porcine vitreous, and frame-by-frame analysis of high-speed video was used to determine duty cycle for each cutter.

The vitreous removal rates of the new-generation, 25-gauge cutter were relatively constant as cut speed increased and were significantly greater than those of the

current-generation cutter at all cut speeds ($P < 0.001$, $P = 0.029$, $P < 0.001$ at 800, 1,000, and 1,500 cpm, respectively).⁸ More significantly, the 25-gauge cutter exhibited greater vitreous flow rates compared with the 20-gauge instrument at higher cut speeds. At 2,000 and 2,500 cpm, the new 25-gauge cutter had 1.45 and 11.88 times the vitreous flow rate of the current 20-gauge cutter ($P < 0.001$), respectively. Although a number of factors influence flow rates, the high and relatively constant vitreous flow rates of the new-generation 25-gauge cutter are most likely because it can maintain significantly higher duty cycles relative to the current-generation cutters at all cut speeds ($P < 0.001$).

The performance of this new-generation, 25-gauge cutter demonstrates the recent advances of vitreous cutter technology, including cut speed and duty cycle. With these optimized parameters, the efficiency of vitreous flow with smaller-diameter cutters matches or exceeds that of current larger-diameter systems. ■

Sophia Y. Fang, Joel M. Cicchella, and Mark S. Humayun, MD, PhD, are with the Eye Concepts research & development laboratory at the Doheny Eye Institute. Dr. Humayun is also in the Departments of Ophthalmology and Biomedical Engineering, University of Southern California. The authors have no financial interest in the products mentioned. Dr. Humayun may be reached at humayun@usc.edu.



**Eye Concepts receives research funds, which are part of an advanced royalty distribution agreement between Bausch & Lomb, Inc., and the Doheny Eye Institute. No financial relationship exists between MID Labs (the manufacturer of the AVE vitreous cutters discussed in this article) and Eye Concepts or the Doheny Eye Institute. Bausch & Lomb, Inc. has nonexclusive distribution rights for the AVE cutters manufactured by MID Labs.*

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