Emerging Techniques in Small-gauge Vitrectomy for Challenging Cases

The latest innovations make the most difficult surgeries less demanding.

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Since Eugene de Juan introduced the current concept of transconjunctival sutureless vitrectomy with a trocar-cannula system and small-gauge instrumentation,[1] numerous advances in technologies and techniques have brought about dramatic changes in pars plana vitrectomy.

As a result, transconjunctival microincision vitrectomy (MIVS), using small-gauge (23- or 25-gauge), instrumentation has emerged as a global standard surgical style of vitrectomy for treating a variety of vitreoretinal pathologies.

Smaller gauges offer numerous benefits over the conventional 20-gauge system, including shorter operating time, reduced corneal astigmatism, diminished conjunctival scarring, improved patient comfort and, in some cases, earlier visual recovery.

Thanks to recent advances in high-end multifunctional vitrectomy machines and ultrahigh-speed cutters, powerful illuminating light sources and chandelier endoillumination systems, and wide-angle viewing systems, several new techniques have emerged, enabling the use of much smaller-gauge systems for treating challenging cases safer and more efficiently.

In this article, I describe the state-of-art surgical settings and techniques in vitrectomy, membrane manipulations, and fundus visualization with small-gauge vitreous surgery systems, as well as the recent advances in technologies.

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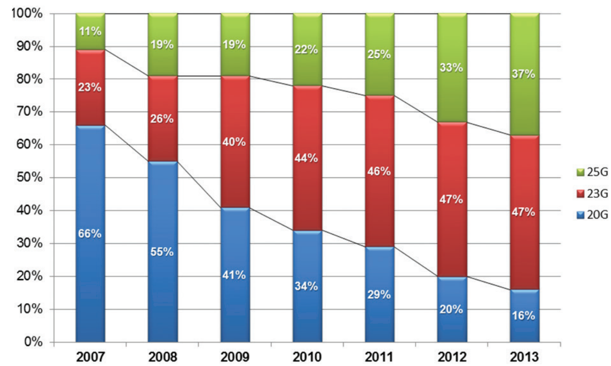

Figure 1. Global survey of surgeons' preference of gauge over the years.

TECHNOLOGIES AND TECHNIQUES FOR VITREOUS CUTTING

Most of the recently developed vitrectomy machines feature high-speed cutters with cutting rates greater than 5,000 cpm. The high cutting speed maintains the duty-cycle at >50%, dramatically improving the vitreous cutting efficiency of small-gauge cutters, even with 25- or much smaller 27-gauge.[2]

This advance has facilitated many surgeons' transitions to smaller-gauge instrumentation for MIVS in recent years (**Figure 1**).

In addition to the improvement of the conventional spring pneumatic–driven vitreous cutter, the dual pneumatic valve–driven vitreous cutter (Ultravit, Alcon Laboratories, Fort Worth, TX) is a new concept for vitrectomy.

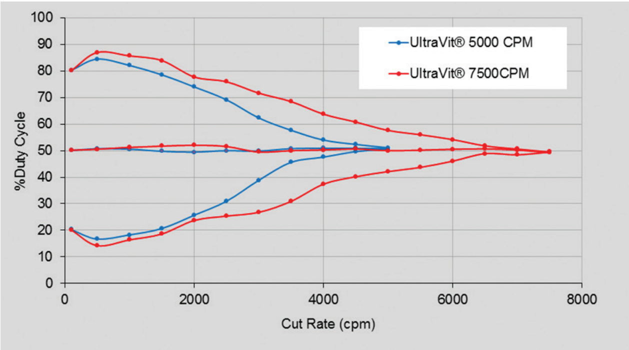

Figure 2. Comparison of duty cycle changes of dual pneumatic driven cutters (5,000 cpm vs 7,500 cpm). The definition of duty cycle is the ratio of the time the port is open in a cut cycle to the overall duration of the cut cycle, which is presented as a percentage. The Constellation three settings, called "core" (port biased open), "shave" (port biased closed), and 50/50. The open biased setting renders the port mostly open in the cutting cycle, maximizing the flow for the given cut rate and vacuum. The closed biased setting renders the port mostly closed in the cutting cycle, minimizing the flow and tractional force for the given cutting rate and vacuum. The reduced bite size at higher cut rates can reduce the resistance to flow and increase the flow rates.

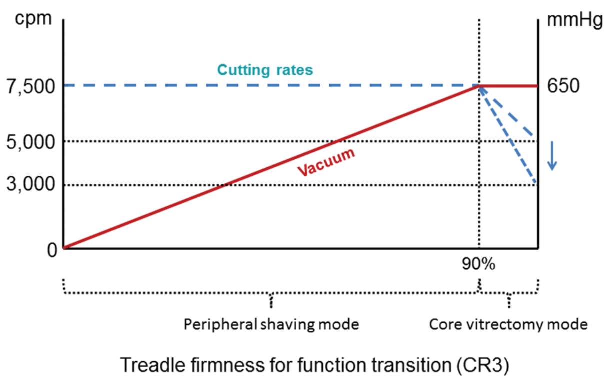

Figure 3. A proposed 3D submode setting for efficient vitrectomy. Core vitrectomy is possible with a full step-in of the foot pedal to maintain the maximum aspiration of 650 mm Hg with higher–duty cycle cutting rates of 5,000 cpm, and safer peripheral vitreous shaving is achievable sequentially by simply releasing the foot pedal to obtain a proportional control of the aspiration, with the highest cutting rate of 7,500 cpm.

This cutter is currently capable of ultrahigh-speed cutting at up to 7,500 cpm, with duty-cycle controls in a variety of situations (**Figure 2**) in corporation with the Constellation Vision System (Alcon).

Flow Rates and Cut Rates

The elegant mechanism that increases or decreases flow without changing the cut rate or vacuum parameters may facilitate more efficient core vitrectomy and safer peripheral vitreous shaving, with less traction force to the retina.[3]

With the latest program featured in the Constellation, two different cutting and aspiration settings can be set sequentially by the foot pedal control, along with the percentage of step-in based on the surgeon's preference (**Figure 3**).

It is very convenient to perform efficient core vitrectomy sequentially, with full step-in of the foot pedal and safer peripheral vitreous shaving, by simply releasing the foot pedal slightly. This technique is especially suitable for cases with retinal detachment, even with the currently smallest 27-g system (**Figure 4**).

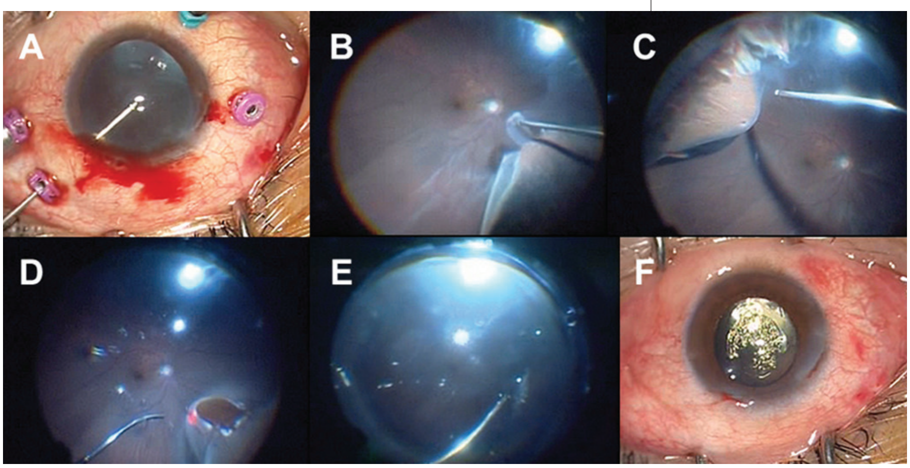

Figure 4. Twenty-seven–gauge vitrectomy system for treating rhegmatogenous retinal detachment. (A) A 27+ valved cannula (purple) system with a 25-g cannula-compatible chandelier illumination fiber (light green). (B) Releasing the vitreous traction around the retinal break with a 27+ UltraVit probe at 7,500 cpm. (C) Peripheral vitreous shaving under scleral indentation. (D) Endophotocoagulation around the retina break with a 27+ curved laser probe. (E) Fluid-air exchange performed with a 27+ soft-tip back-flush needle probe. (F) Surgical view at the inclusion of 27+ vitrectomy after cannula removal.

Double-port Cutter

In addition, the concept of the double-port cutter, featuring a second port in the internal guillotine blade of the cutter, incorporates into the spring-pneumatic driven cutter to improve the flow efficiency by maintaining the duty cycle without attenuation while increasing the cutting rate.[4,5]

This approach may be another step forward in flow efficiency during small-gauge vitrectomy. However, further studies are needed to evaluate the potential risk of increasing the traction force on the vitreous with this type of cutter because the cutting port is almost fully open.

TECHNIQUES FOR MEMBRANE REMOVAL

Cutter Techniques

Several studies have shown that transconjunctival MIVS has several advantages over conventional 20-g instrumentations for diabetic vitrectomy.[6-8] The conjunctiva-preserving nature of MIVS permits repeated vitrectomy or filtering surgery, which may be necessary in diabetic patients with neovascular glaucoma, even after vitrectomy.

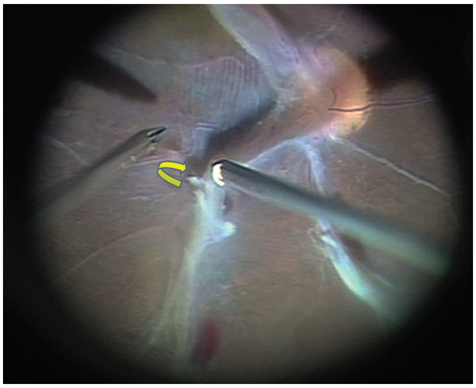

Figure 5. Foldback membrane delamination with a 25-g cutter. The cutter port is placed just behind the membrane's leading edge, and the surgeon folds back the membrane into the port (yellow arrow) by high-speed cutting in shave mode with gently aspiration.

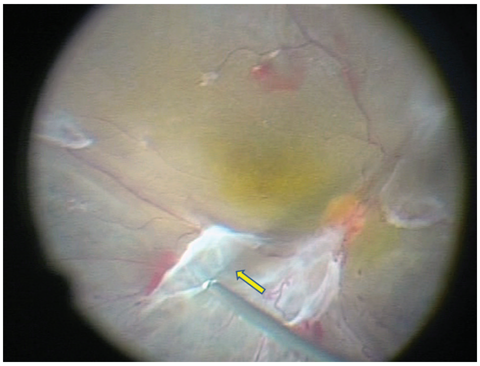

Figure 6. Conformal membrane delamination with a 25-g cutter. The thickened membrane can be dissected directly by moving the cutter port forward into the leading edge of the membrane (yellow arrow) and adjusting the port away from the retina to reduce the risk of retina entering the port.

The surgical techniques for removing diabetic fibrovascular membranes during MIVS differ from those in conventional 20-g vitrectomy. Because the distances from the ports to the tips in the small-gauge vitreous cutter are shorter than those of a conventional 20-g vitreous cutter, the cutters can serve as multifunctional tools during membrane removal.

The port of the 23-, 25-, or 27-g cutter can be inserted readily between the fibrovascular membrane and retina, facilitating successful membrane segmentation, dissection and removal using a small-gauge vitreous cutter only.

The result is less of a need to use complex instruments, such as scissors, picks, and spatulas, for fibrovascular membrane removal in most cases.

Small-gauge Membrane Dissection

Steve Charles has proposed several different techniques using a small-gauge cutter for membrane dissection, which Dr. Charles has called "cutter delamination."[9]

"Foldback delamination" (**Figure 5**) is a very useful and safe technique for removing flexible, weakly fixed membranes by putting the cutter port just behind the membrane's leading edge and folding back the membrane into the port, with high-speed cutting in shave mode and gentle aspiration. The membrane existing between the cutter port and the retina may reduce the potential risk of causing iatrogenic breaks.

Thickened fibrovascular membranes, large blood clots, and retained lens fragments can also be engaged and excised with the small-gauge cutter, facilitated by reduced cut rates (**Figure 6**).

Thickened Membranes

In cases with thickened membranes, I prefer to use the "conformal cutter delamination" technique, also proposed by Dr. Charles. The surgeon can dissect the thickened membranes directly by moving the cutter port forward into the leading edges of the membranes, adjusting the port away from the retina to reduce the risk of retina entering the port.

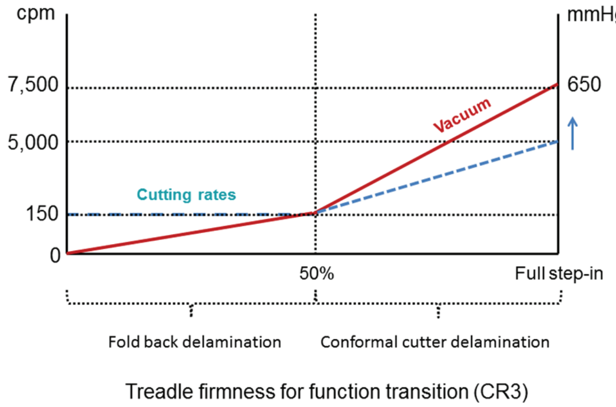

Figure 7. A proposed 3D submode setting for cutter membrane delamination. The two different cutter settings for cutter membrane delamination can be switched and adjusted quickly and sequentially by foot pedal control.

In conjunction with the latest program featured in the Constellation, the current two-cutter delamination settings can be customized sequentially, as shown in **Figure 7**. The surgeon can switch the two different techniques quickly by rotating or repositioning the cutter port, changing the step-in percentage to control the preferred cutting setting, depend on the thickness and fragility of the fibrovascular membranes.

which is originally proposed by Shunsuke Osawa, MD, from Iga, Japan,

Tips and Indications for Bimanual Maneuvers

The current widespread use of chandelier endoillumination, in conjunction with wide-angle viewing systems, has improved the ability to perform bimanual intraocular manipulation with small-gauge instruments in challenging cases.[10]

Under panoramic viewing, we no longer need to move the globe with surgical instruments to visualize the periphery. As a result, we have far fewer feelings of frustration over the fragility of small-gauge instruments during vitrectomy.[11]

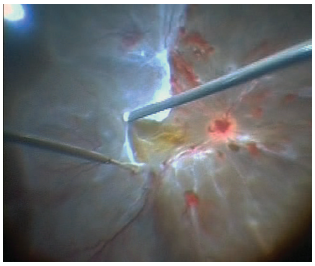

Figure 8. Bimanual dissection of fibrovascular membranes in diabetic cases. The membrane forceps allows the surgeon to grasp the edge of membrane to introduce the blunt tip of the cutter easily into the tiny spaces between the detached retina and adherent membranes.

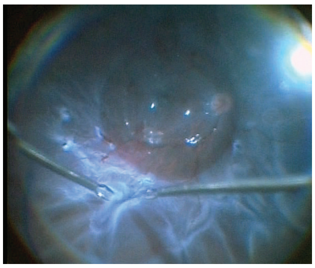

Figure 9. Bimanual membrane peeling in cases with proliferative PVR. Using two forceps for peeling the strongly adherent membrane is a safe technique to avoid creating iatrogenic breaks.

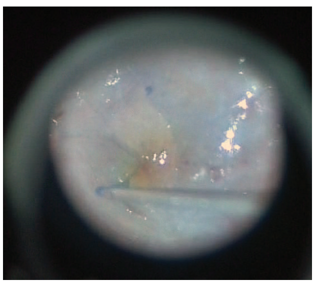

Figure 10. Membrane peeling under perfluorocarbon liquid. Peeling off the membranes stained by BBG and Trypan blue beneath perfluorocarbon liquid is a helpful technique to flatten and stabilize the detached retina for membrane peeling with small-gauge forceps

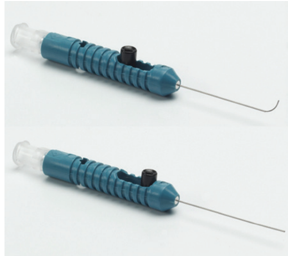

Figure 11. A 25-g directional visco-cannula for visco-delamination. The curvature and length of the inner cannula are adjustable and extendible by pulling the adjuster.

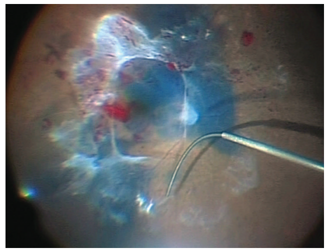

Figure 12. The tip of the inner cannula can be inserted into the tiny spaces between the fibrovascular membrane and the retina. The areas where the posterior hyaloid detachment was created can be clearly visualized with BBG-conjugated viscoelastics.

In addition, chandelier endoillumination allows the surgeon to have one hand free to manipulate and depress the globe. These two advances have facilitated quicker, safer, and more thorough removal of the membranes from detached or mobile retina bimanually with small-gauge instruments.

Although in most cases the membranes can be peeled, dissected, and removed with a single hand because of the multi-functionality of the cutter, patients with combined traction and rhegmatogenous retinal detachment due to extensive fibrovascular membranes or those with PVR with adhesive pre- or subretinal membranes are strongly indicated for bimanual membrane dissection or peeling using small-gauge vitrectomy.

Diabetic Vitrectomy

In diabetic cases, I usually use a membrane forceps with a vitreous cutter to grasp and dissect broad membranes. With panoramic viewing, the forceps can engage the edge of the membrane easily to introduce the blunt tip of a small-gauge cutter into the tight space between the detached retina and adherent membranes (**Figure 8**). The combination of forceps with curved scissors is another option.

Surgically adjunctive use of an anti-VEGF drug is an effective option for minimizing the likelihood of intraoperative bleeding. However, if bleeding occurs during membrane removal, the combination of a diathermy probe with a buck-flush needle or a cutter is a helpful strategy to determine the bleeding point by active aspiration with immediate pinpoint hemostasis.

Another option is the proportional reflux function to splash out the blood for immediate pinpoint cauterization. Both techniques are very helpful in keeping the bleeding from reobscuring the bleeding point, which we often see during instrument exchange with single-hand manipulation.

Proliferative Vitreoretinopathy

In PVR cases, using two forceps for peeling strongly adherent membranes is a safe technique to avoid creating iatrogenic breaks (**Figure 9**). It is also very useful to peel of the subretinal stands or membranes from small intentional retinal holes, using small-gauge instruments in a hand-to-hand manner to avoid enlarging the retinal hole.

To visualize the transparent premature membranes, staining the membranes with a solution of mixed Trypan blue and brilliant blue G (BBG) dyes is a useful technique for concurrently visualizing both preretinal membranes (by Trypan blue) and the ILM (by BBG).

Membrane peeling under perfluorocarbon liquid is also helpful for flattening and stabilizing the detached retina for membrane peeling with small-gauge forceps (**Figure 10**).

Visco-delamination Technique

Visco-delamination is a well-known technique, initially reported in the 20-g era using hydraulic force to separate the strongly adherent posterior hyaloid or premature fibrovascular membranes from the retina in diabetic cases.[12]

The indications for this technique are limited to a small spectrum of cases in which a PVD has not occurred at all or is very localized. In addition, the surgeon should be cautious to avoid hydraulic force tearing the retina and misleading the viscoelastic into the subretinal space.

Nevertheless, visco-delamination is a worthwhile technique for the above-described indicated cases, to introduce or extend a focal PVD for subsequent maneuvers.

A New Visco-Cannula

Recently, Synergetics Inc. (King of Prussia, PA) introduced a specially designed directional visco-cannula for 25- or 27-g surgery (**Figure 11**). The curvature of the inner cannula is adjustable and extendible.

For visco-delamination, I prefer the inside-out approach to the outside-in approach described because the central retina is stronger than the retina outside the arcades.

After creating a small approaching space around the disc area with a membrane pick, the surgeon can easily insert the tip of the extendible inner cannula into the tiny spaces between the fibrovascular membrane and the retina.

As shown in **Figure 12**, I prefer to inject BBG-conjugated viscoelastics for visco-delamination because it is easier to visualize the areas where a PVD has been created. Once an appropriate area of PVD exists, I recommend a transition back to an ultrahigh-speed cutter for subsequent membrane dissection.

SUMMARY

The most recent surgical technologies and techniques in small-gauge vitrectomy simplify surgical procedures, improve the safety and efficiency of surgery, reduce operating time, and lower the chances of encountering complications, even in challenging cases.

The current state-of-the-art surgical techniques used with high-end vitrectomy machines and wide-angle visualizing systems offer the best surgical options for using much smaller-gauge systems, resulting in even less invasive surgery in challenging cases.

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