Microsurgery for Vitreoretinal Diseases: Evolution of Vitrectomy

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Most vitreoretinal conditions were left to their natural history before the advent of vitrectomy. Since the first vitrectomy was reported, almost 4 decades ago, the equipments, techniques, indications and outcome of vitrectomy have been continuously improved to become modern vitrectomy techniques that is minimally invasive a procedure performed with patients under local anesthesia and can be done as a day surgery.

Thirty-eight years ago, in 1968, David Kasner, MD is credited with his report on the first successful treatment of open-sky vitrectomy technique. The open-sky technique means the procedure employed for removing the lens and cornea before vitrectomy was performed. The vitrectomy was done by using a wet cellulose sponge to remove the vitreous from the pupil by scissors before it was replaced with saline. After then, the patient's cornea was sewn back in place and the patient was left aphakic. At that time, the benefit of vitreous removal and replacement with saline was highly controversial. Kasner performed several vitrectomies with open-sky technique in traumatic and post-cataract eyes that had sustained vitreous loss and found that the old concept, that vitreous gel was necessary and its removal would cause eye collapse, was untrue.

In 1971, Robert Machemer, MD and his team developed an automated method for removing the vitreous gel via open-sky approach. The shaft of automated vitrectomy instrument consisted of a drill bit that was encased in a metal tube and the vitreous was aspirated through an opening at the end of the tube and was repeatedly cut by the rills of the drill. The motor was mounted at the other end of the instrument to rotate the shaft; the vitreous was mobilized up through the shaft, and suction was manually created by a syringe. After that the instrument was designed to entry via pars plana, instead of open-sky, to avoid cornea removal and lensectomy. The vitrectomy was viewed by microscope and lens system through the pupil. An infusion cannula was added to the instrument to prevent the eye from collapse. The diameter of the instrument was 1.5 mm (17 gauges). To make the procedure less invasive and better result, in 1974, O'Malley C and Heintz RM invented a small vitreous cutter with a diameter of 0.89 mm (20 gauge) and subsequently pioneered a three-port vitrectomy system by separating pars plana infusion port from vitreous cutter port and endoillumination port, which became the standard technique for vitrectomy commonly used today. After that many new innovations in vitrectomy instrument and technique were invented and developed to enhance the result of surgery for vitreoretinal diseases.[1] (Fig 1)

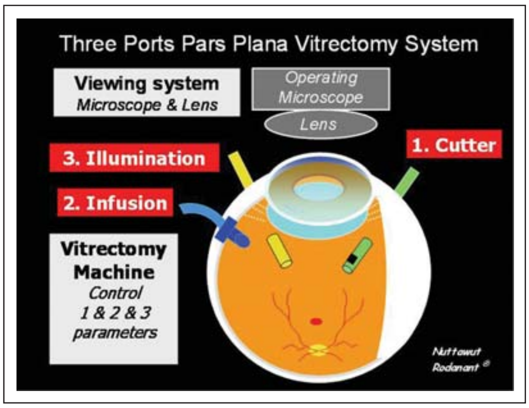

Fig 1. Three ports pars plana vitrectomy system.

The standard three-port pars plana vitrectomy depends on four essential systems: vitreous cutter and other intraocular instruments, infusion system, illumination system, and viewing system.

The vitreous cutting devices aspirate small amount of vitreous into an opening near the end of the device and cut the vitreous off into small pieces by a rotating or guillotine blade in a high speed (up to 2000 cut per minute) to reduce the traction force when remove the vitreous from the retina. The cutter speed and the aspirate pressure were controlled by a vitrectomy machine. The intraocular micro instruments are include scissor (manual or automated), forceps, pick, fragmatome, diathermy probe, laser probe, aspiration tips, magnet and also multifunctional instruments such as combined light with forceps or laser, combined laser with extrusion, etc..

The infusion cannula is used to infuse a physiologically fluid (e.g., balanced salt solution, silicone oil, heavy silicone oil, perfluorocarbon liquid), air or gas (e.g., SF6, C3F8) to replace the vitreous that was removed by vitreous cutter and keep the eye formed in normal contour. Varieties of vitreoretinal conditions need different type of vitreous substitutes for retinal temponade. The infusion port was sutured to the sclera. The intraocular pressure is regulated by a pump in the vitrectomy machine or by the height of the solution container.

The illumination system is a fiber optic instrument that delivers the light from the light source in the vitrectomy machine or separated light source, and emits the light from the end of a fiber optic to create visualization of the vitreous and retina during vitrectomy via an operating microscope and lens system. Later, the illumination system was combined with the infusion port and also a self-retained illumination port as the 4th port was developed so that the illumination probe did not need to be held by one hand as in the standard 3-port vitrectomy system. This has allowed the surgeon to perform bimanual vitrectomy.

Using operating microscope in conjunction with lens viewing systems, the vitrectomy can be performed. Many types of lens systems are developed for viewing of retina and vitreous in direct or indirect (wide-angle) view by contact or non-contact system. The direct viewing systems allow greater magnification and enhanced stereopsis but allowing smaller field for viewing compared with the indirect viewing system. The advantages of the indirect visualization include a wider field for viewing, better visualization through miotic pupils, gas-filled eyes and media opacities.

The number of vitreoretinal conditions that vitrectomy is helpful is increasing. The major vitrectomy indications are clear vitreous opacities, better access to the retina and subretinal space to remove or treat pathologic conditions, tissue biopsy, removing vitreous scaffold to decrease further retinal traction, and replacing vitreous with vitreous substitute.

In 1990, Eugene de Juan, Jr started to developed 25 gauge (0.5 mm diameter) vitrectomy instruments that allow self-sealing incision and minimal invasive. Twelve years later, in 2002, a new 25 gauge instruments system for transconjunctival sutureless vitrectomy (TSV) surgery was reported with reduced surgical time, reduced patient discomfort, and shortened postoperative recovery.[2] There are some limitations because of its smaller size and diameter, the 25 gauge instruments is increase flexibility, the cannula has a lower infusion and aspiration rate compared to the 20-gauge system so the setting in vitrectomy machine must be increased (500 mmHg for aspiration with maximum cut rate) to decrease the possibility of aspiration line obstruction. However, a dense tissue can occasionally obstruct the aspiration line and cutter. Some potential complications specifically related to the 25-gauge system are wound leak and hypotony in early postoperative period, even though normal intraocular pressure is usually re-established within one week but some cases may require suturing. TSV are not suitable for retina surgical procedures that required extensive intraocular maneuver, such as complicated cases of severe vitreoretinopathy or severe tractional retinal detachment from proliferative diabetic retinopathy and cases where the use of silicone oil or buckle is anticipated. It appears to be ideal for the more common procedures include epiretinal membrane peeling, macular hole, persistent macular edema, vitreous hemorrhage, uncomplicated traction or rhegmatogenous retinal detachment, and cases with coexistent filtering bleb. TSV is compatible with the smaller pedriatric eyes and helpful in lens-sparing vitrectomy.

Ophthalmic endoscopy 3 has been developed since 1934, Thorpe combined telescope with intraocular forceps, with outer diameter of 6 mm. In 1981, Norris and Cleaseby employed a 1.7 mm diameter glass rod endoscope for vitrectomy. Then in 1985, argon laser endophotocoagulation fiber was added to the 1.7 mm endoscope for intraocular cyclophotocoagulation in primate eyes by Shields. Six years later, in 1991, ophthalmic endoscopic evolved to the next important transition, the 20-gauge (0.89mm) ophthalmic laser endoscope using 3000 pixel fiberoptic imaging bundle and intrinsic laser fiber. The human endoscopic photocoagulation of retina was reported and the commercially ophthalmic endoscope was available.

Ophthalmic endoscopy is valuable in two broad areas: first in visualization of internal view of the eye despite anterior segment opacities (cornea, anterior chamber, iris, lens); second in visualization of inaccessible or difficult to access regions of the eye (area behind iris, ciliary body, pars plana, ora serata, peripheral retina).

Even though there are many types of endoscopes and their combinations, they share the same basic characteristics. The most commonly used form in ophthalmology is the fiberoptic type of endoscope. Ophthalmic endoscopy is combined with two sets of components. The first component is the endoscope probe or handpiece connected with the second component which includes the illumination source, laser sources, and video endoscopy systems. The surgeon monitors the course of procedure on video monitor without stereopsis instead of operating microscope.

Ophthalmic endoscope probe is a handpiece with a distal metal tube end of intraocular portion that typically 30 mm in length with the outer diameter of 0.89-1.4 mm. The handpiece contains combined sets of image optical fibers, illumination optical fibers with or without laser optical fibers bundled together. Each individual image fiber provides a tiny part of a picture that is called a pixel. Theoretically, the more pixels, the more resolution improves with the better image. However, an increase in pixel number is also an increase in the diameter, cost, and fragility of the instrument. The current standard is the 10,000 pixel. The most commonly used field of view is 110 degree with the depth of field from 0.75 to 4 mm that created by the objective lens on the distal tip of the fiberoptic image probe. The image is transmitted throughout the length of a fiber optic and then passed into a set of lens for fine image focus and for magnification just before entered CCD chips of a video camera. The image quality (color, sharpness, contrast, brightness, etc.) can be adjusted before transmission to the monitor. The illumination is typically xenon light source with multiple illumination fibers (about 35-80) that would create a 110 degree cone of light. The fiberoptic laser endoscope is the most commonly used form of laser in ophthalmic endoscope. The laser fiber is built into the endoscope so that there is no channel to pass the laser fiber as the standard non-ophthalmic endoscopes. Laser sources used in ophthalmology can be combined with endoscopy, including argon, frequency-double Nd:YAG, and 810 nm diode laser.

During the past four decades, vitreoretinal surgery has evolved to treat diseases previously untreatable with new instruments and techniques. The future of the vitreoretinal surgery will develop new innovation, techniques and instrumentations combined with adjuvant therapies such as chemical vitreolysis, retinal transplantation, retinal prosthesis, intravitreous drug delivery devices, gene therapy etc. to increase our ability of treatment and improve the benefit of patients.

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