

The History of Vitrectomy: Innovation and Evolution

BY STEVE CHARLES, MD



Ventures in Translation features innovators in the field of vitreoretinal disease. Successful translation of scientific ideas to useful medical treatments and technologies requires many elements. Each of the innovators featured here has a story to tell that often combines an exceptional understanding of disease, foresight, perseverance, and an ability to obtain funding for an unrecognized technology.

In this installment, Steve Charles, MD, provides a narrative of the evolution of vitrectomy, sharing his unique perspective as a participant and a witness to this significant evolution.

-Elias Reichel, MD

The history of vitrectomy is a story of the interrelated development of a vast array of techniques and evolution of technique-driven technology. David Kasner developed open sky cellulose sponge vitrectomy prior to machine-based vitrectomy; initially to address the problem of vitreous loss at cataract surgery. He later used the technique to remove opaque vitreous through a penetrating keratoplasty incision. Many surgeons had injected air, various gases, silicone oil, and saline in the vitreous, aspirated liquid vitreous, and used scissors in the vitreous cavity prior to development of a mechanized vitreous cutter.

CUTTER TECHNOLOGY

Robert Machemer developed closed, pars plana vitrectomy to eliminate the need for keratoplasty and operate with a closed system with controllable intraocular pressure. Machemer did the first clinical cases of pars plan vitrectomy and was the crucial element resulting in the development of a systematic approach to vitreoretinal surgery and a distinct vitreoretinal surgery subspecialty. A vitreous cutter with infusion and aspiration was developed and used clinically in Japan prior to development of vitrectomy in the United States but this was published in the Japanese literature and apparently not known in the United States. Anton Banko patented a vitreous cutter including aspiration and infusion prior to the development of the VISC by Jean Marie Parel and Machemer but never commercialized the device. Banko, who developed the fluidics for the initial phacoemulsification machine for Charles Kelman, had

knowledge of mechanized lens removal systems invented by Kelman prior to the application of ultrasound, and saw vitreous often during the development of clinical phacoemulsification. Jean Marie Parel developed the VISC, fiberoptic endoillumination, and the solenoid operated MPC vertical scissors. Working with Machemer, Nicholas Douvas developed the RotoExtractor which, like the VISC, was a full-function, large incision, rotary cutter but incorporated an oscillatory mode to address the vitreous winding problem of the VISC. Conor O'Malley and Ralph Heinz developed three-port vitrectomy with a 20-gauge (0.89 mm) system as well as a lightweight, reusable, bellows-driven, pneumatic, axial cutter driven by the Ocutome 800 console (Berkley Bioengineering, 1972). Gholam Peyman developed the electric solenoid driven axial (guillotine) cutter at about the same time R. Kloti in Europe developed a three port system with an electric cutter.

TAMPONADES

I invented internal (through the retinal break) drainage of subretinal fluid to address the many complications of transscleral drainage: incarceration, bleeding, and incomplete drainage. I developed simultaneous internal fluid-air exchange, now just called fluid-air exchange, to eliminate the problems of sequential exchange: hypotony, incomplete exchange, and having a needle in a deflated eye. I developed air-gas exchange and air-silicone exchange to produce a complete exchange of air for so-called tamponade substances without fluctuation in intraocular pressure. Brooks McEwen developed the air pump which replaced using a

syringe for fluid-air exchange. The air pump produced a controllable intraocular pressure and was never depleted. Carl Wang and I developed the first power gas injector and first power silicone injector. I invented vacuum cleaning using a straight cannula with a fingertip side port to control fluid egress (flute needle) but soon switched to Conor O'Malley's technique of extrusion, using the console aspiration system and foot pedal to control fluid egress. David McLeod and Peter Leaver combined John Scott's technique of injecting silicone oil without vitrectomy with my fluid-air exchange, internal drainage of subretinal fluid, and endophotocoagulation technique; creating the currently utilized paradigm. Edward W. D. Norton and Harvey Lincoff independently developed the use of gas injection in conjunction with scleral buckling leveraging much earlier, independent work by Ohm and Rosengren. Gary Abrams developed the concept of using an iso-expansive gas concentration leveraging my techniques of fluid-air exchange, internal drainage of subretinal fluid followed by air-gas exchange. The use of iso-expansive gas-air mixtures produced near full fill bubbles without producing elevated intraocular pressure. Stanley Chang developed the use of perfluorocarbon (heavy) liquids to unfold giant breaks and stabilize the retina during PVR membrane dissection. Machemer and I independently and simultaneously developed both retinectomy (relaxing retinotomy) as well as subretinal surgery.

ENDOPHOTOCOAGULATION

I developed endophotocoagulation to allow retinopexy, hemostasis, and pan retinal photocoagulation without corneal or iris damage and adapted the technique to three-port vitrectomy. My first system used the Zeiss xenon source while my first commercial system used a xenon source (Patrick O'Malley's Log III photocoagulator); subsequently Maurice Landers, Jay Fleischman, and I simultaneously and independently developed endophotocoagulation systems using an argon laser source, later Yasuo Tano developed the near-IR diode laser source and finally Alcon and Iridex developed 532 nm, diode pumped sources.

MEMBRANE PEELING

Machemer developed membrane peeling using a bent needle. Conor O'Malley developed the pic for membrane peeling which was safer because it did not have sharp point. I developed end-grasping forceps membrane peeling to enable safe, one-step epiretinal membrane without the need for needles, pics, dyes, or viscodissection. I developed diamond-coated membrane peeling forceps and conformal forceps which afforded a better purchase than earlier forceps designs. I developed scissors segmentation to shear adherent, epiretinal membranes that could be peeled into separate epicenters to reduce tangential traction. I devel-

oped scissors delamination of epiretinal membranes to completely remove adherent epiretinal membranes without dangerous peeling. Yasuo Tano developed the diamond-dusted membrane scraper and Brooks McEwen developed the micromanipulator which combined a pic with a light source and diathermy. Stanley Chang developed the end-aspirating laser probe which allowed simultaneous drainage of subretinal fluid and laser retinopexy.

TWENTY-GAUGE VITRECTOMY TECHNOLOGY

I developed linear (proportional) control for the Ocutome 8000 working with engineers at CooperVision after they had acquired Berkley Bioengineering, the developers of the Ocutome 800. Linear suction was developed to enable control of vacuum by the surgeon rather than the circulator. Carl Wang subsequently left CooperVision (Fairport, NY) to start the original MidLabs; I worked with Wang and his engineers to develop the disposable, 20-gauge, pneumatic, axial cutter and higher cutting rates and faster aspiration fluidics. Although I did not own stock or receive any compensation, I helped grow the company until it was acquired by Alcon Laboratories, Inc. (Fort Worth, TX).

In the mid-80s I started InnoVision and invented the Ocular Connection Machine, the forerunner of the Alcon Accurus and subsequently the Alcon Constellation. I used the OCM in the operating room as did several other surgeons but it was never commercialized; the technology was acquired by Alcon Laboratories, Inc., in 1991 and I became a consultant for Alcon Laboratories, Inc. The OCM had a xenon light source, servo-controlled intraocular pressure (IOP), global functions, a smart key graphical user interface, tool ID, a tubing management system incorporated into a sterile articulated arm, the dual actuation InnoVit (no spring), 1,500 cpm, push prime, and proportional diathermy all of which are implemented on the new Alcon Constellation. The Constellation uses RFID instead of the more primitive tool ID system on the OCM. The OCM began the revolution of system integration, a steadily increasing number of functions in one console under unified control using a graphical user interface.

MICROINCISION VITRECTOMY SYSTEMS

The Accurus took 5 years to develop and included global functions, a smart key driven graphical user interface, the dual actuation InnoVit, a halogen light source, power silicone injector, fragmenter driver electronics, power scissors and ultimately supported 23- and 25-gauge vitrectomy as well as 2,500 cpm vitrectomy. I did not receive compensation when the OCM technology was acquired by Alcon and did not receive a royalty on the Accurus.

In addition to servo-controlled IOP, global functions, a smart key graphical user interface, tool ID, a tubing management system incorporated into a sterile articulated arm, dual actuation, and proportional diathermy described above the Constellation has variable duty cycle control, auto-gas fill, auto-stopcock for fluid air exchange, dual xenon illumination sources, power silicone injector, and supports over 5,000 cpm.

Dyson Hickingbotham developed the first trocar-cannula system for 1.0 mm tools but it never became popular until Eugene DeJuan working with Bausch & Lomb brought us sutureless, transconjunctival, 25-gauge vitrectomy. Alcon developed a better trocar-cannula system and a disposable 25-gauge cutter. Dutch Ophthalmic Research Centre (DORC) first introduced 23-gauge vitrectomy working with Klaus Eckardt and Alcon subsequently developed a single step 23-gauge trocar-cannula system. The introduction of 23 gauge after 25 gauge implied to many surgeons that 23 gauge combined the best attributes of both systems; in my view 25 gauge is better for all cases. The Constellation 25-gauge UltraVit has much less fluidic resistance than previous 25-gauge systems and provides the same performance as current 23-gauge systems. All the Constellation tools have greater stiffness than the previous generations of tools which also makes the case for 23 gauge less tenable.

The original approach to wide-angle viewing was con-

tact-based using the Rodenstock panfunduscope without an inverter. Subsequently, Manfred Spitznas developed the BIOM noncontact system and Stanley Chang developed the AVI contact-based wide-angle system, which uses a Volk lens and an inverter. Contact-based wide-angle visualization provides 10° greater field of view than noncontact systems (BIOM and EIBOS), eliminates corneal asphericity, and decreases the need for ocular rotation (tool flex) to view the periphery.

I believe the future will bring a greater understanding of fluidics, the physics of vitreous removal and tissue cutting, providing greater safety and utility for the cutter when working near the retinal surface. I do not think non-mechanical cutting or enzymatic vitrectomy will replace mechanical devices. ■

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