A lesson in history: the evolution of endoscopic third ventriculostomy

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The history of endoscopic third ventriculostomy (ETV) demonstrates the importance of studying neurosurgery’s history. A story that began with numerous technological advancements started to fizzle as neurosurgeons were stymied by problems encountered during the infancy of the technology they were still developing. The new technique, although sound in theory, failed to deliver a realistic solution for managing hydrocephalus; it lost the battle to the valved shunt. Over the last 15–20 years, a clearer understanding of pathophysiological mechanisms underlying various forms of hydrocephalus, along with effective implementation of evidence-based practice, has allowed for optimization of patient selection and a remarkable improvement in ETV success rates. Neurosurgeons would be wise to take the lessons learned in modernizing the ETV procedure and reassure themselves that these lessons do not apply to other methods that are tempting to dismiss as antiquated or archaic.

Key Words • third ventriculostomy • neuroendoscopy • history of neurosurgery

Early Endoscopy

The history of the endoscope has been written on extensively, but it is worth summarizing the major developments. As detailed by Abbott and others,1,3,24 Antonin Desormeaux is credited with developing the first endoscope, which he presented to the Parisian Academy of Medicine in 1853. His was a cystoscope that made use of a kerosene light source originating from the base of the handle. The lamplight was reflected into the bladder by a concave mirror with a central hole set at 45 degrees. Desormeaux successfully demonstrated his device by removing a papilloma from a patient’s urethra, the first recorded therapeutic use of an endoscope.

Abbreviations used in this paper: CCD = charge-coupled device; ETV = endoscopic third ventriculostomy; ETVSS = ETV Success Score.
technicians at the University of Berlin), and eventually Joseph Leiter (a well-known Vienna instrument maker), he developed the Nitze-Leiter cystoscope (Fig. 1).\textsuperscript{1,8,13,17,24} The scope made use of Bruck’s internal lighting system (cooled by a separate water circulation) along with a prism, and also used a series of lenses to magnify the user’s view of the bladder.

**Intracranial Endoscopes**

Viktor Lespinasse secured a place in history as the first neuroendoscopist in 1910.\textsuperscript{1,8} He treated 2 children with hydrocephalus by using a urethroscope to access the lateral ventricles, where he performed a fulguration of the choroid plexus.\textsuperscript{24} However, Walter Dandy is considered by most to be the father of neuroendoscopy.

In 1922 Dandy described ventriculoscopy,\textsuperscript{3} as well as a technique for performing the third ventriculostomy as a treatment for hydrocephalus via frontal and subtemporal approaches.\textsuperscript{6} Dandy’s open attempts at puncturing the floor of the ventricle were true skull base approaches. These challenging forays into the base of the brain yielded dissatisfaction with the morbidity and mortality encountered in performing craniotomies for ventriculostomy. Thus, Dandy attempted and described an endoscopic approach to the same procedure. Dandy used a funnel-like instrument (Fig. 2), in combination with a head mirror, to perform the first endoscopic choroid plexectomy to treat hydrocephalus. However, his early attempts at minimally invasive choroid plexectomies were met with more frustration, and he reverted to conventional craniotomies.\textsuperscript{3,24} Dandy continued to tinker with the design of his ventriculoscope in an effort to make it suitable for intracranial maneuvering; by 1932, he was again attempting an endoscopic choroid plexectomy. However, as recounted by Hsu et al.,\textsuperscript{8} in reviewing his 1945 text *Surgery of the Brain*, Dandy remarked that while occasions may arise where direct visualization of the ventricles is necessary, “it seems hardly probable.” His frustrations with the ventriculostomy were not as much related to the failure of the procedure as they were to the morbidity and mortality associated with the open approach.\textsuperscript{9} In retrospect, he may have been more enthusiastic if he could have adequately visualized the ventricular anatomy via the less invasive endoscopic approach. Other emerging endoscopists must have agreed, because the years following Dandy’s description of the third ventriculostomy and endoscopic choroid plexectomy were dominated by innovations revolving around improving and miniaturizing the endoscopic light source.

William Mixter was the first surgeon to combine diagnostic ventriculoscopy with the ventriculostomy.\textsuperscript{3,8,24} In 1923 he used a urethroscope to perform an ETV to treat noncommunicating hydrocephalus in a 9-year-old girl.\textsuperscript{15} In reviewing Mixter’s report, it is interesting to see that by the time his article went to publication, he had already written an addendum noting the recently published work by Fay.
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and Grant. They successfully used a ventriculoscope to develop black-and-white images of the ventricle.1,13

Tracy Putnam cited the work by Dandy and Mixter as influential in his development of the coagulating ventriculoscope in 1934.15,24 Putnam developed an instrument specifically for intracranial procedures, which contained a single glass rod for viewing, along with 3 grooves to allow for a bronchoscope light and 2 electrodes. The major limitation to Putnam’s ventriculoscope was that visualization was limited to only those surfaces that were in contact with the end of the glass rod.

As noted by Li et al.,13 in 1935 John Scarff made an important observation regarding the fenestration of the ventricle, remarking on “the necessity of enlarging the opening beyond a mere puncture wound.” Scarff made several modifications to the endoscope that made it highly adapted to intraventricular surgery, namely: a “fore-oblique” lens system that allowed simultaneous viewing of forward and wide-angle fields, a mobile unipolar electrode, a light, and an irrigation system that could replace CSF lost during the procedure, thus maintaining a constant pressure during the operation. Scarff would continue to use this design for nearly 30 years, with the only modification being a conversion to a fiberoptic light in 1963.13,22,23

William McNickle would make one of the final advancements in performing the third ventriculostomy in 1947,14 before a period of relative silence that fell in concert with the arrival of valved shunts.24 McNickle described a method of percutaneous ventricular puncture; more importantly, he noted that “In the past, third ventriculostomy has been reserved for cases of non-communicating hydrocephalus…. The division of hydrocephalus into communicating and non-communicating types is an arbitrary one, and has been over-emphasized.” In recent years it has become more clear that our predecessors’ success rates with ventriculostomy were not limited as much by technology as they were by poor patient selection. The distinction between communicating and non-communicating hydrocephalus was losing importance.

The Era of the Shunt

A discussion of CSF diversion with shunts would be an encyclopedic undertaking beyond the scope of the current review. After the introduction of the shunt by Nulsen and Spitz in 1951,10 the third ventriculostomy quickly fell from favor. A few individuals continued to explore a physiological solution to the problem of hydrocephalus. Their continued efforts to prove that the procedure was worth remembering prevented it from becoming an anecdotal curiosity.

Guiot combined a bright external light source with a quartz rod, which provided the illumination necessary to develop pictures in color; he asserted that ventriculostomy under ventriculographic control was a safe procedure.1

Hoffman et al.7 reported on more than 700 ventriculostomies—one-third were performed percutaneously with stereotactic guidance, and the rest were open craniotomies—and found that their mortality rate was cut by more than half when they performed the procedure percutaneously. The Methods section of their manuscript notes the following patient selection criteria:

1. The hydrocephalus must be of an obstructive nature, and the lateral and 3rd ventricles must not be occluded by neoplastic masses. Obstruction will be at the level of the aqueduct or the outlets of the 4th ventricle.

2. As a corollary of Point 1, the subarachnoid spaces must be potentially patent. Patients with confirmed meningitis should therefore not be considered as candidates.

3. The 3rd ventricle must be grossly dilated, and its floor should extend behind and below the dorsum sellae. Any attempt to operate on a small 3rd ventricle will result almost inevitably in a poorly executed lesion and subsequent blockage.

4. The patient must not have been shunted before 3rd ventriculostomy.

The oldest child in the series published by Hoffman et al. was 3 years old; with that exception, these authors have outlined criteria for patients in whom the ETVSS (discussed later) would predict a benefit from a successful ETV. Although their results no doubt benefited from meticulous trajectory planning and avoidance of collateral damage to nearby structures, it may have been just as beneficial that they were optimizing their patient population.

In 1996, Rieger et al.20 used ultrasound guidance for ventricular fenestrations. Ultrasound, they reported, was as accurate as stereotaxy, with a less time-consuming setup. Two years later, Rohde et al.21 described a combination of frameless stereotaxy and neuroendoscopy; they believed that the combined technique could reduce morbidity.

The advancement of MRI techniques also influenced some ventriculostomy techniques. Burtscher et al.4 described an MRI-assisted virtual endoscopy, which allowed preoperative visualization of hidden vascular anatomy.

In 2002, Krombach et al.19 combined MR endoscopy with frameless stereotaxy, again in an attempt to plan for avoidance of possible vascular obstacles. They additionally were looking to optimize their planned trajectory to avoid moving the rigid endoscope intraoperatively, because movement can damage the nearby parenchyma. Although it is true that movement of the endoscope can cause collateral damage, it is not clear that such damage had been a limiting factor in the success or failure of previous ETV series.

Zimmermann et al.25 reported on their experience in which they used a robot to perform their ventriculostomies in 2004. Although the robot added a significant amount of time to the preoperative preparations, the operative times were reported as being comparable to free-hand operations, with improved precision.

Modern-Day Third Ventriculostomy

The modern neuroendoscopist is afforded a high-definition view of intraventricular anatomy (Fig. 3). When comparing the equipment used today with that used by our predecessors, it is easy to overemphasize the importance of the technological discoveries underlying the progression of neuroendoscopy. Most of the reports regarding third ventriculostomy during the last 40 years have not been centered on the actual procedure, but instead on
the associated technology. As stated at the outset of this review, there is a unique history lesson in the evolution of the ETV. Despite the technological marvels that allowed for clearer intraventricular views and more precise localization of vascular structures, some of the greatest leaps came about through effective hypothesis testing and relentless inquiry into CSF physiology. A more detailed understanding of CSF dynamics led to the description of more specific subtypes of hydrocephalic patients; precise categorization then facilitated improved patient selection.

The two most influential technological discoveries that propelled neuroendoscopy were the CCD and fiber-optics. The first CCD was invented by Smith and Boyle at Bell Laboratories in 1969. The CCDs provided a remarkable improvement in the quality of the optical data that could be transmitted by increasingly smaller instruments. Fiber-optics, first described by Scarff in 1963 as “fiber lighting,” consisted of incoherent and coherent fiber bundles that allowed the respective transmittal of light and visual information.

In his 2004 report on patient selection for ETV, Harold Rekate advises, “Every shunt failure or infection should be viewed as an opportunity to explore the possibility that the patient could become shunt independent.” Rekate explains that the fundamental criterion of successful patient selection for an ETV is an obstruction between the third ventricle and the cortical subarachnoid spaces. Building on “the importance of the cortical subarachnoid space in understanding hydrocephalus,” Rekate et al. released a report of precisely that title in 2008 that beautifully describes CSF dynamics, specifically regarding the role often ignored cortical subarachnoid space plays in various forms of hydrocephalus.

Rekate et al. discuss the misconceptions surrounding communicating and noncommunicating hydrocephalus, and why these terms can be confusing when attempting to predict patients who may benefit from ETV. Students of history, the authors point out that their issue with the current nomenclature had actually been noted 50 years prior by Ransohoff et al., who recommended that the terms “extraventricular obstructive” and “intraventricular obstructive” be substituted for “communicating” and “non-communicating” in discussing the origins of hydrocephalus.

In 2009, the Pediatric Neurosurgery Study Group described the ETVSS. The ETVSS was a retrospective analysis of 618 ETVs performed at 12 different institutions. A multivariate logistic regression model identified age, origin of hydrocephalus, and the presence or absence of a previous shunt as being most predictive of a successful procedure at 6 months. The ETVSS is still evolving, and it should not be considered the sole algorithm for assessing who should and should not undergo an ETV.

The ability to accurately predict long-term success of a shunt-independent solution for hydrocephalus is an invaluable tool, especially when considering treatment in areas of the world where convenient neurosurgical intervention, or even regular follow-up, may be difficult. Likewise, in these environments, a lack of advanced imaging techniques during initial evaluation could prevent implementation of more technology-dependent ETV selection algorithms.

Conclusions

With the introduction of the valved shunt system and its apparent success rate, the third ventriculostomy was mostly abandoned. Shunting has been considered a successful endeavor, but the constant need for maintenance of malfunctioning shunts, coupled with major technological advances in the field of endoscopic surgery, prompted a renewed interest in third ventriculostomy as a means of managing hydrocephalus. It has become evident that the decline of the third ventriculostomy as a means of treating hydrocephalus was largely due not to the lack of suitable equipment, but to unacceptable rates of morbidity and mortality. A clearer understanding of pathophysiological mechanisms underlying various forms of hydrocephalus, along with effective implementation of evidence-based practice, has allowed for optimization of patient selection and a remarkable improvement in ETV success rates. We would be wise to take the lessons learned in modernizing the ETV and reassure ourselves that they do not apply to other methods that we are tempted to dismiss as antiquated or archaic.

Disclosure

The authors report no conflict of interest concerning the mate-
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