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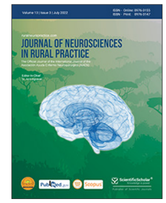

Review Article

Ventriculoureteral shunt: Narrative review of contemporary cases and its historical role in the development of renal transplantation

Andrew Leland Waack[1], Alastair T. Hoyt[1], Jason L. Schroeder[1]

[1]Department of Surgery, Division of Neurosurgery, University of Toledo, Toledo, Ohio, United States.

ABSTRACT

Ventriculo-ureteral (VU) shunting is a little-known method of managing hydrocephalus. This paper reviews contemporary uses of this shunting technique and describes its historical significance to the field of organ transplantation. The ureter may serve as a possible backup, or alternative, distal drainage site compared to the more common peritoneum, atrium, and pleural space. Sporadic contemporary uses of the VU shunt have been reported in unique situations, demonstrating a possible utility in modern neurosurgery. Interestingly, the VU shunt played an important role in the development of kidney transplantation. In the late 1940s and early 1950s, David Hume, a general surgery resident, and colleagues at the PBBH undertook a series of human kidney transplantations. Concurrently, Donald Matson, a pediatric neurosurgeon at Peter Bent Brigham, was utilizing the VU shunt in hydrocephalic patients. Dr. Matson's VU shunt technique involved total nephrectomy, and some of the kidneys harvested from Dr. Matson's were used by his general surgery colleagues in their transplantation trials. Although none of the transplanted kidneys from this series were successful, the transplant team in Boston, minus David Hume, went on to perform the world's first kidney transplant a few years later. This relatively unfamiliar procedure may be applicable to specific situations, and it is of historical importance to the field of transplantation.

Keywords: Shunt, Hydrocephalus, Ureter, Transplantation, History

INTRODUCTION

Hydrocephalus is a common neurosurgical condition. The management of hydrocephalus has ancient roots, from Hippocrates first describing the condition, to Vesalius localizing the condition to the ventricles, to the first attempts at percutaneous drainage by Charaf ed Din and Hildanus in the 15th and 17th centuries.[1] Following the advent of modern neurosurgery, Walter Dandy was the first to systematically investigate the anatomy of the ventricles; he notably described communicating and non-communicating forms of hydrocephalus. Following Dandy's work, various surgical approaches were implemented. Some techniques, such as Scarr's choroid plexectomy, aimed to decrease cerebrospinal fluid (CSF) production. Other approaches, such as Torkildsen's ventriculocisternostomy or Dandy's third ventriculostomy, sought to divert CSF flow around obstructions.[1] A variety of shunting procedures were developed to drain excess CSF out of the ventricular system for relief of both communicating and non-communicating hydrocephalus, with ventriculoperitoneal (VP), ventriculoatrial (VA), and ventriculopleural (VPl) shunts developing into the most popular contemporary shunting techniques.

The VP shunt is the most commonly used procedure to relieve hydrocephalus. These shunts provide adequate relief for the majority of patients; however, there are several commonly encountered complications, including shunt obstruction, infection, bowel perforation, abdominal pseudocyst formation, and overdrainage with possible subsequent subdural hematoma.[2] Revision surgeries are often required and 11–25% of patients require revision in the 1st year alone after surgery.[2] Alternative targets for distal shunt placement may be needed to be identified. The VA shunt, in which the distal tip is placed into the venous system, is the most common alternative to VP shunting.[3] VA shunting is also associated with several complications, including obstructions, malpositioning, infections, and cardiac complications.[3] Other complications include microembolism formation and glomerulonephritis.[1] The VPl shunt is another commonly used alternative to VP shunting. VPl shunts divert CSF into the pleural space, where the CSF can be reabsorbed. VPl shunting may lead to complications, including pleural effusions, pneumothorax, and empyema.[4] Other options exist when VP, VA, and VPl shunts have failed. In fact, 36 different ventricular shunt locations have been reported,

*Corresponding author: Andrew Leland Waack, Department of Surgery, Division of Neurosurgery, University of Toledo, Toledo, Ohio, United States. awaack98@gmail.com

Received: 11 December 2022 **Accepted:** 01 January 2023 **EPub Ahead of Print:** 23 February 2023 **Published:** 03 May 2023 **DOI**: 10.25259/JNRP_68_2022

including the pleura, gallbladder, and lymphatics.[5] CSF can also be diverted to the urinary system by shunting to the kidney, ureter, or bladder.[5]

NARRATIVE REVIEW

The ventriculoureteral (VU) shunt is a little known alternative to VP or VA shunting in which CSF is diverted to the ureter and excreted in urine. The origins of CSF diversion to the urinary system began in 1925 when Heile (who was also the first to shunt into the pleural space) placed lumbar-ureteral shunts in four patients with communicating hydrocephalus.[6] In 1948, Donald Matson, considered one of the "fathers of pediatric neurosurgery," elaborated on Heile's technique and treated a case of post-meningitis communicating hydrocephalus in an 8-year-old girl with the use of a lumbar-ureteral shunt.[7] In 1951, Matson described the "ventriculouretostomy," a surgery he had designed to divert ventricular CSF directly to the urinary system via the ureter.[8] Surprisingly invasive, both Heile's and Matson's procedures involved unilateral nephrectomy of a healthy kidney for ureteral shunt placement.[6-8] Furthermore, CSF diversion into the urinary excretion causes fluid and electrolyte loss in the urine.[9] It is believed homeostatic mechanisms regulating fluid intake are capable of compensating for this loss,[10] but dehydration and electrolyte imbalances can occur, especially when challenged with diarrhea, vomiting or electrolyte abnormalities.[9] Other side effects have been reported, including ureter spasm, encrustation, ureter wall erosion, ascending infection (UTI associated or non), biofilm formation, retrograde urine reflux, catheter migration, failure of urinary diversion, and tube disconnection/migration.[9-13] Furthermore, most neurosurgery training programs do not include training in genitourinary surgery, so assistance from a urologist may be indicated.[11] Despite these issues, however, the VU shunt was an accepted shunting method before the development of the one-way valve because of the ureter's hydrodynamic resistance.[1] Understandably, the VU shunt fell out of favor when superior shunting techniques emerged. Today, the VU shunt is little more than an obscure footnote in neurosurgery history, although there are reported cases utilizing modified VU shunts.

Sporadic cases utilizing modified versions of the original VU shunt have been reported and these reported cases demonstrate successful management of hydrocephalus that has failed VP and VA shunting.

There have been a few contemporary reported cases utilizing the VU shunt after failure of other shunting methods. Notably, nephrectomy sparing VU techniques were developed by Smith and Pittman, in which the ureter was transected, followed by shunt placement into the distal ureter stump and proximal ureter reimplantation to the urinary bladder.[14,15] Since then, other nephrectomy-sparing modifications have been implemented, including minimally invasive percutaneous nephrostomies.[9,10] Many reported cases present favorable outcomes. In a series of 4 cases using VU shunting, the reoperation rate was less than the rate for VP or VA shunts, with an average revision rate of once every 3.5 years, as opposed to 2–3 revisions/year in VP or VA shunts.[16] A 4-year-old boy who developed hydrocephalus secondary to intraventricular hemorrhage with a history of several prior abdominal surgeries for bowel perforations and renal transplantation seemed especially suitable for a VU shunt. 1 year following surgery no complications were reported.[13] A VU shunt with ureter implantation into a psoas bladder without nephrectomy presented with no side effects 3 months after shunt placement.[17] Finally, two cases were reported to have no side effects at 4 weeks and 1.5 years following VU placement.[18] Additional cases were considered successful at relieving hydrocephalus, but they did report treatable side effects; reported side effects included ureter spasm,[9] dehydration and electrolyte disturbance,[10,11] high wound output,[11] infection,[12,16] shunt displacement,[16] and tube kinking.[16] VU shunting is a relatively unknown procedure that should be considered for appropriate patients. Although uncommon, VU shunting can provide utility in managing hydrocephalus, as contemporary techniques no longer necessitate nephrectomy, and either open or percutaneous approaches allow surgeons easy access to the ureter.

HISTORICAL VIGNETTE

Interestingly, the VU shunt contributed greatly to the field of renal transplantation. As stated previously, the VU shunt was developed and utilized by Dr. Donald Matson.[19] Dr. Matson trained at (Peter Bent Brigham Hospital [PBBH]) (now Brigham and Women's Hospital) under Franc Ingraham, Harvey Cushing's immediate successor at PBBH. Drs Matson and Ingraham later practiced together at PBBH, where the two of them became the "fathers of pediatric neurosurgery," writing the book Neurosurgery of Infancy and Childhood. Matson eventually succeeded Ingraham to serve as Chairman of the Department of Neurosurgery at Boston Children's Hospital and PBBH. He also served as the President of the American Association of Neurological Surgeons (then the Harvey Cushing Society) in 1968, Editor of Journal of Neurosurgery and Secretary and Chairman of the American Board of Neurological Surgery.[19] While Matson was developing the field of pediatric neurosurgery, his medical and general surgery colleagues at PBBH were revolutionizing kidney care through their work in dialysis and kidney transplantation. The advancements made at PBBH were due in large part to excellent leadership, provided by George Thorn and Francis Moore. The culture of interdepartmental collaboration between these medical legends at PBBH led to breakthroughs that have since revolutionized medicine and saved countless lives.

PBBH had a long history of innovation in renal care. Physicians George Thorn and John Merrill made great contributions to the field of nephrology.[20,21] Of particular interest, these two physicians collaborated with Willhelm Kolff, the inventor of the "artificial kidney," to improve Kolff's artificial kidney. The team subsequently developed the improved "Kolff-Brigham Kidney."[21] Notably, the ability to dialyze patients was vital for the development of transplantation, as this technology helped manage kidney recipients during episodes of kidney failure. However, both Thorn and Merrill knew that dialysis would not provide a cure, just symptom relief. They recognized the role that transplantation could play in curing renal failure.

Meanwhile, Dr. Francis Moore was Chief of Surgery at PBBH, where his leadership created the culture necessary for pursuing transplantation.[22] In 1951–1953, David Hume, then a surgical resident, conducted a series of 9 human kidney transplants without any form of immunosuppression. Using local anesthesia, he placed the donor kidney in the thigh by connecting the renal artery and vein to the femoral artery and vein and drained urine into an external collection bag by channeling the ureter out through the skin. The medical management of these nine patients varied, with some patients getting ACTH and/or corticosteroids, most getting heparin, and all receiving testosterone.[23] Two of the kidneys in this trial were supplied by nephrectomies performed by Matson during VU surgeries. One of the live donors was a 2-year-old girl who had a subarachnoid-ureteral shunt placed for a communicating hydrocephalus, and the other was a 33-year-old woman who had a VU shunt placed for a tumor blocking the cerebral aqueduct.[23] Without any form of immunosuppression, the overall results of the study were poor, prompting Hume *et al*. to conclude "at the present state of our knowledge, renal homotransplants do not appear to be justified in the treatment of human disease."[23] As such, the researchers retreated back to their laboratories to further study the immunology of organ rejection. In addition, Hume's cases showed that the thigh was not an ideal location for heterotopic transplantation, due largely to a predisposition to infection through the skin-ureterostomy and challenges in the drainage of urine; consequently, Murray used a different heterotopic location for kidney placement in his landmark surgery.[24] Although unsuccessful, Hume's trial provided valuable input to the transplant team, allowing them to better prepare for later transplant attempts.

A golden opportunity later presented itself when Merrill was contacted regarding a set of identical twins, one of whom had developed renal failure secondary to chronic nephritis. Richard Herrick was admitted to PBBH, and, after extensive workup, was deemed suitable for transplantation. His twin brother Ronald agreed to donate one of his kidneys to his brother. Joseph Murray conducted the world's first successful kidney transplantation on December 23, 1954, grafting a kidney from Ronald to Richard Herrick. This surgery proved that organ transplantation was technically feasible in man, but it did not address the issue of immunological rejection.[25] Encouraged, the transplant team continued to search for an effective means of achieving adequate immunosuppression to extend the purview of transplantation. The transplant team subsequently went on to play a central role in developing adequate immunosuppression, helping to make transplantation a routine medical procedure.

CONCLUSION

The VU shunt is an uncommon procedure that is rarely utilized in modern neurosurgery. However, this technique may be appropriate in certain clinical scenarios. Additionally, this technique has an interesting link to the development of transplant surgery.

Declaration of patient consent

Patient's consent not required as the patient's identity is not disclosed or compromised.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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How to cite this article: Waack AL, Hoyt AT, Schroeder JL. Ventriculo-ureteral shunt: Narrative review of contemporary cases and its historical role in the development of renal transplantation. J Neurosci Rural Pract 2023;14:210-3.