

Critical Review of Shunting Procedures for Hydrocephalus

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ABSTRACT

The authors analyzed 174 consecutive shunting procedures for hydrocephalus at Severance Hospital, Yonsei University.

There were a total of 65 complications (48.5 %) among 134 patients. The most common complications were blockage of the catheters (26.2%) and shunt-related infections (15.4%).

Among the different types of shunting technique ventriculoatrial, ventriculoperitoneal and ventriculocisternal routes were most commonly used. The ventriculoatrial route had a greater complication rate (40%) than ventriculoperitoneal shunting (21.8%). Flushing devices are critically reviewed and the disadvantages are discussed.

The authors suggested a need for a standardized prospective national data collection system where procedures and compilations may be assembled in a comparable form.

INTRODUCTION

Comprehensive reports of shunting procedures are concentrating on ventriculoatrial (Illingworth, 1970; Nulsen and Spitz, 1952; Shurtleff, *et al.*, 1971) or ventriculoperitoneal shunts (Ferguson, 1898; Jackson and Snodgrass, 1955). No single report has satisfactorily

detailed for a reasonable comparison of the results of both ventriculoatrial (Irving, *et al.*, 1971; Matson, 1953; Pudeng, *et al.*, 1957), and ventriculo-peritoneal shunting (Ames, 1967; Ferguson, 1898; Hammon, 1971) procedures. Unfortunately the majority of the series report a bias in favor of either V-A or V-P. The nature of hydrocephalus, the hydrodynamic pattern of hydrocephalic processes, age, sex (Washburn, *et al.*, 1965), timing of surgery (Provenzano, *et al.*, 1965; Rosen and Janeway, 1964) and all the different types of shunting devices do not allow any unique pattern in surgical results. With the presently available techniques of detecting a malfunction of the shunting, no clinical and/or laboratory findings are absolute in indicating a malfunctioning. This fact is particularly true when the series includes symptomatic hydrocephalus. Thus there arise certain difficulties in telling if the clinical features are due to the primary disease itself or to malfunctioning of the shunting.

While a number of reports detail the complications of ventriculoatrial shunting procedures (Davidoff, 1929; Kloss, 1969; Shurtleff, *et al.*, 1971), rather less data are available concerning the use of ventriculoperitoneal shunting procedures.

This study is a retrospective review of all patients shunted at Severance Hospital from 1967 to 1976. During those years 174 shunting

procedures were performed on 134 hydrocephalics. The data are strictly itemized and the complications and results are critically reviewed.

METHOD AND RESULTS

A statistical comparison was made between age, sex of the patients and complication rate. Table 1 presents the age and sex distribution of 134 hydrocephalics. The patients are tabulated into 2 groups; the first, patients under 1 year of age, and 20 patients were in this group. The second, patients over 1 year of age, comprises 114 patients (85%). There is no significant sex difference between the groups.

Hydrocephalus was classified according to etiology into congenital and symptomatic. 17 cases (13%) had either one of aqueductal stenosis, meningocele, Arnold-Chiari malformation or Dandy-Walker cyst. The majority (102 cases, 76%) showed postmeningitic, posttraumatic, normotensive, hydrocephalus associated in origin with brain tumor and/or spontaneous subarachnoid hemorrhage. For 15 cases cause was unknown (Table 2).

Type of shunting surgery is shown in Table 3: Among the 174 shunting operations the ventriculoatrial route was most commonly instituted, 84 times, then ventriculopleural ventriculocisternal and ventriculopleural shunt in that order. Lumboperitoneal shunt was installed in 1 case. The Holter device was instituted 57 times, and the "valveless" one

piece shunt 70 times, which included 38 shunting procedures (Torkildsen procedure) for

Table 2. Etiologic Classification of Hydrocephalus

Hydrocephalus	No. of cases
Congenital	17
Aqueductal stenosis	6
Meningocele	7
Arnold-Chiari malformation	2
Dandy-Walker cyst	2
Postmeningitic	21
Posttraumatic	7
Normotensive	2
Hydrocephalus ass. with brain tumors	63
Supratentorial	19
Infratentorial	49
Hydrocephalus ass. with spont. SAH	4
Unknown	15
Total	134

Table 3. Type of Shunting among 174 Procedures for Hydrocephalus

Type of shunt	Name of device	No. of cases	Total
V-A*	Holter	46	84
	Pudenz	21	
	Denver	2	
	Valveless	15	
V-P**	Holter	11	39
	Denver	8	
	Unishunt	14	
	Hakim	2	
	Valveless	4	
V-Pleural	Valveless	12	12
V-Cis***	Valveless	38	38
Lumbo-Peritoneal	Valveless	1	1
Total			174

* V-A: Ventriculoatrial

** V-P: Ventriculoperitoneal

*** V-Cis: Ventriculocisternal

Table 1. Age and Sex Incidence of 134 Hydrocephalics with 174 Procedures

Age	No. of cases	Sex	No. of cases
Under 1yr (7.9 mon)	20	M	76
Over 1yr (21.6 yr)	114	F	53
Total	134	Total	134

Table 4. Overall Complications of 174 Shunting Procedures on 134 Hydrocephalics

Complications	Total No. of complications	%
Blockage of catheters	17	26.2
Proximal	11	
Distal	6	
Seizure, postoperative	12	18.5
Infection	10	15.4
Valve malformation	7	10.8
C.S.F. leakage along the shunt tract	5	7.7
Disconnection of catheters	4	6.1
Regional hematoma	3	4.6
Abscess	2	3.1
Fever (FUO)	2	3.1
Catheter shortening	1	1.5
Kinking of catheters	1	1.5
Hernia, inguinal	1	1.5
Total	65	100.0

posterior fossa tumors. In early 1967 ventriculopleural shunting was instituted in 12 cases,

for shunting was complicated for other routes and by lack of other shunting materials.

There were a total of 65 complications (48.5%) among 134 patients. The most common complications were blockage of catheters (26.2%), convulsive seizures postoperatively (18.5%) and infections (15.4%). Virtually shunt tubing related complications were 53.8% among all, comprising blockage of catheters, valve malfunction, CSF leakage along the shunt tract, disconnection of catheters, catheter shortening and kinking of catheters. The next most common group of complication was infection related in 21.6% (Table 4).

The valveless one piece catheter system showed the highest rate of complications, 40%, and the next was the Holter valve system, with 32.3%. It was interesting that 7 out of 21 complications among the shunts with Holter devices were from valve malfunction, with changing of the pressure valve system in 3

Table 5. Total No. of Complications in Relation to Shunting Devices

Complications	Name of shunting device						Total No. of cases
	Holter	Pudenz	Denver	Hakim	Valveless	Unishunt	
Blockage of catheters							17 (26.2%)
Proximal	3	3		1	2	2	11
Distal	1				5		6
Disconnection of catheters	1	2			1		4 (6.1%)
Kinking of catheters					1		1 (1.5%)
Valve malfunction	7						7 (10.8%)
Catheter shortening	1						1 (1.5%)
Infection	1	1	2		6		10 (15.4%)
Fever (FUO)	1	1					2 (3.1%)
C.S.F. leakage along the shunt tract	1	1	1		2		5 (7.7%)
Regional hematoma	1				2		3 (4.6%)
Abscess			1		1		2 (3.1%)
Seizure, Postoperative	3	2	1		6		12 (18.5%)
Hernia, inguinal	1						1 (1.5%)
Total	21 (32.3%)	11 (16.9%)	4 (6.2%)	1 (1.5%)	26 (40.0%)	2 (3.1%)	65(100.0%)

cases. The Pudenz device had 11 (16.9%) complications. The results with the Denver, Hakim and Unishunt did not allow statistical significance determination because the total number of the operations was small at the time of followup. At any rate the experience with Unishunt, which showed blockage of the catheter only on 2 occasions, was quite encouraging to the authors (Table 5).

Table 6. List of Complications among Shunting Revisions

Complications	No. of complications	Total (%)
Blockage of catheters	17	(42.5%)
Proximal	11	
Distal	6	
Disconnection of catheters	4	(10.0%)
Kinking of catheters	1	(2.5%)
Valve malfunction	7	(17.5%)
Catheter shortening	1	(2.5%)
Infection	4	(10.0%)
C.S.F. leakage along the shunt tract	4	(10.0%)
Abscess	2	(5.0%)
Total	40	(100.0%)

It was noticeable that the complications that led shunt revision were mostly shunting system related, blockage of the catheters (42.5%) or valve malfunction (Table 6).

Table 7 illustrates numbers of complications among the different types of shunting operations. In 40 occasions it was thought that the complication was surgery per se related. Ventriculoatrial shunting had by far the highest rate (60%) of complications, compared to the rest of ventriculoperitoneal shunting (17.5%) and the ventriculopleural method. The results of the relatively small numbers of complications among ventriculocisternal shuntings come from the difficulty of evaluating the status of shunting, for it is deeply installed in the posterior fossa.

The result of both ventriculoatrial and ventriculoperitoneal shuntings are compared by the revision rate (Table 8): 60 ventriculoatrial procedures had 24 revisions (40.0%) and 7 revisions (21.8%) followed 32 ventriculoperitoneal shuntings. Not only did ventriculoatrial shunting show a higher rate of revision but also the complications are often life threatening and less correctable compared to ventriculoperi-

Table 7. No. of Complications per Type of Surgery

Type of surgery Complications	Ventriculo-atrial	Ventriculo-peritoneal	Ventriculo-pleural	Ventriculo-cisternal	Total (%)
Blockage of catheters					17 (42.5%)
Proximal	8	3			11 (27.5%)
Distal	3	1	2		6 (15.0%)
Disconnection of catheters	3	—	1		4 (10.0%)
Kinking of catheters	0	—	1		1 (2.5%)
Valve malfunction	5	2			7 (17.5%)
Catheter shortening	1	—			1 (2.5%)
Infection	1	1		2	4 (10.0%)
C.S.F. leakage along the shunt tract	2	—		2	4 (10.0%)
Abscess	1	—		1	2 (5.0%)
Total	24 (60.0%)	7 (17.5%)	4 (10.0%)	5 (12.5%)	40(100.0%)

Table 8. Total Rate of Complications among V-A and V-P Shunting Procedures

Type of shunting	Total No. of op.	No. of revisions	Percentage
V-A	60	24	40.0%
V-P	32	7	21.8%

Table 9.

Complications per		
patients	65/134	(48.5%)
per procedure	65/174	(37.4%)
Revision rate	40/134	(29.8%)

toneal shunting.

Among the different disease processes in which shunting procedures were done, there were 40 shunt revisions among 134 cases (29.3%) and 65 complications, thus, 48.5% per patient and 37.4% per procedure of shunting (Table 9).

For complications there was no significant difference among those who were before and after 1 year of age. Male patients overall had a higher rate of complications among these two different age groups (Table 10).

DISCUSSION

The policy each center adopts upon the issues of hydrocephalus obviously will influence each

center's reportable shunting complications. Moreover, cultural dispositions, age, sex and mobility of each neurosurgical center's referral or out patient population will influence reported results. And finally, the subjective inclinations and reportive techniques of the neurosurgical center will influence the patterns of complication results. An extraordinary number of collected studies reveal in great detail the complications involved in ventriculoatrial (Anderson, 1959; Illingworth, 1970; Kloss, 1968) shunts. They emphasize the dangers of blocking of the shunting and subsequent shunt infections (Overton and Snodgrass, 1965; Schinke, *et al.*, 1961; Strenger, 1963). Rarer complications include thrombosis of the superior or inferior vena cava (Nugent, *et al.*, 1966; Overton and Snodgrass, 1965), occlusion of the pulmonary artery and/or pulmonary emboli (Emery and Hilton, 1960; Erdahagi, *et al.*, 1966; Sperling, *et al.*, 1964), migration of the catheter into the pulmonary artery (Illingworth, *et al.*, 1971; Long, *et al.*, 1964), cardiac tamponade (Anderson, 1959; Dzenitis, *et al.*, 1965; Strenger, 1963), and subdural hematoma (Illingworth, 1970).

Ventriculoperitoneal shunting also presented many complications which comprised disconnections, severance, migration of the shunting tube (Adeloye, 1973; Patel and Matloub, 1973; Ramani, 1974), obstruction of either the vent-

Table 10. Complications in View of Age & Sex

Among 20 patients under 1 year of age		Among 114 patients over 1 year of age	
Sex	No. of complications	No. of complications	
M	6 (60.0%)	35 (63.6%)	
F	4 (40.0%)	20 (36.4%)	
Total	10(100.0%)	55(100.0%)	
	10/20 (50.0%)	55/114(48.2%)	

ricular or peritoneal ends by proteinaceous materials or choroid plexus and/or brain debris, abdominal cysts (Dean and Keller, 1972; Fischer and Shillito, 1969), subdural hematomas (Illingworth, 1970) and the formation of a proteinaceous film over the surface of the distal end of the shunt tubing within the peritoneal cavity etc. (Ferguson, 1898; Murtagh and Lehuan, 1967; Rosenthal, *et al.*, 1974): with the slit valve at the peritoneal end of the catheter it was noted that the omentum could not insinuate itself into the distal end of the (Raimondi and Matsumoto, 1967) catheter. Consequently, obstruction at the distal end diminished considerably as a complicating factor. It had been considered that the length of tubing and the positioning of the tubing into the peritoneal cavity affects adversely the efficacy of a shunting system. With time, however, it became clear that the length of tubing or its positioning over the liver had little or nothing to do with obstruction or avoidance of it (Harsh, 1954; Ingram, *et al.*, 1947; Jackson and Snodgrass, 1955).

The main factors determining obstruction remained the occlusion of the proximal end by either choroid plexus or the accumulation of brain debris within the shunt tubing and kinking of the shunt tubing along its tract (Becker and Nulen, 1968). Our results with different shunting technique and various shunting devices disclosed that by far our most ubiquitous complications are shunt tubing related (53.8%). It is difficult to show that one type of shunting surgery produces a better prognosis as a rule. However our statistics disclosed that ventriculoperitoneal shunting procedures had a far lower rate of complications (17.5%) compared to ventriculoatrial shuntings (60.0%), and the revision rate for ventriculoatrial shunting was 40% but 21.8% for

ventriculoperitoneal shunting procedures (overall, revision rate per patient 29.8%).

The higher rate of proximal blockage of the shunting catheters rather than the distal in our series may be interpreted by the fact that 102 cases (76%) had symptomatic hydrocephalus associated with brain tumors etc., in which the probability of shunt obstruction was higher than any other hydrocephalus of congenital origin. The Holter shunting device was more often used than any other, and this showed mechanical failure in 7 occasions among 21 Holter device related complications (Table 5). Repeated and traumatic tap into the ventricular system may eventually involve a higher rate of obstruction to shunting. The authors assumed that the higher rate (18.5%) of postoperative seizures was from trauma into the ventricular system or from rapid decompression of the ventricle with eventual shifting of the midline structures of the brain. It is stressed that ventricular decompression should not be too much to rapid.

Proper placement of the ventricular shunt tubing at the foramen of Monro, as suggested by Becker and Nulen (1963), diminished considerably the number of cases of obstruction of the proximal tubing by the choroid plexus. The use of a spring catheter diminished the complications secondary to kinking of the shunt tubing. The slit valve at the distal end of the shunt tubing eliminated the insinuation of omentum (Raimondi and Matsumoto, 1967). It has, over the years, been noted that a common cause of failure of the shunting system is a blockage and that, in turn, necessitates frequent shunt revisions; the occurrence of shunt revision is associated with separation of the various components of the shunting system (ventricular catheter, flushing device, right angle connector, straight connector, distal catheter etc.).

Various flushing devices have been used with the supposition that one could either determine the functioning state of the shunting or "flushing out" obstructing debris from either the distal or proximal ends by compressing the flushing bladder. Neither of these has been proved since a flushing device may depress and return readily and still not be functioning. Compression of the flushing device has not permitted the surgeon to clear out the occluding debris. Repeated daily massages of the flushing device by the family or the physician neither maintain the shunt in functioning order nor permit one to compensate for a poorly functioning system. Therefore, the flushing device has no reliable value as an indicator of a functioning system or in purging an occluded system, or in maintaining in good functioning order of marginally functioning system. The real disadvantages are skin necrosis and bacterial colonization in the reservoir. Connections such as the right angle connector, the double lumen reservoir, or the straight connector change the flow characteristics through the tubing by diminishing and/or increasing the inner diameter and add, thus, to the complexity of the shunting system. Fixing the shunting tube to the connections with suture material often results either in tying down too tightly and cutting the plastic tubing, or tying snugly with disconnection of the system eventually. The need, therefore, arose for an one piece shunt system since no real advantages, and many unacceptable disadvantages existed in the multiunit system.

The authors suggest the need of a standardized prospective national data collection system where procedures and compilations may be assembled in comparable form. Such an innovation might well start with a commonly accepted form of reporting complications with mortality

in neurosurgical center yearly reports.

CONCLUSION

1. Surgical results of 174 shunting procedures for hydrocephalus are presented and critically reviewed.

2. Blocking, valve malfunctioning and disconnection of catheters remained major complications of shunting procedures. The infection-related group was the next most common among complications.

3. The complication rate among infants with congenital hydrocephalus and other anomalies was no higher than for older children or adults receiving shunting procedures for space occupying lesions etc.

4. There is a tremendous difficulty in evaluating comparable statistics obtained from various institutions reviewing shunting procedures and complications.

5. A necessity for a standardized prospective national data collection system is suggested.

REFERENCES

- Adeloye, A.: *Spontaneous extrusion of the abdominal tube through the umbilicus complicating peritoneal shunt for hydrocephalus. J. Neurosurgery* 38:758-760, 1973.
- Ames, R.H.: *Ventriculo-peritoneal shunts in the management of hydrocephalus. J. Neurosurgery* 27:525-529, 1967.
- Andersen, F.M.: *Ventriculo-auriculostomy in treatment of hydrocephalus. J. Neurosurgery* 16:551-557, 1959.
- Becker, D.P. and Nulen, F.E.: *Control of hydrocephalus by value regulated venous shunts: avoidance of complications in prolonged shunt maintenance. J. Neurosurgery* 28:215-225, 1968.
- Davidoff, L.M.: *Treatment of hydrocephalus: historical review and development of a new*

- method. *Arch. Surg.* Vol. 18:1737-1762, 1929.
- Dean, F.B. and Keller, I.B.: *Cerebro-spinal fluid ascites: a complication of ventriculo-peritoneal shunt.* *J. Neurosurgery, Neurol., Psychiatry* 35:474, 1972.
- Dzenitis, A.J., Mealey, J., Jr. and Waddill, J.R.: *Myocardial perforation by ventriculo-atrial shunt tubing.* *J.A.M.A.* 194:1251-1253, 1965.
- Emery, J.L. and Hilton, H.B.: *Lung and Heart complications of the treatment of hydrocephalus by ventriculo-stomy.* *Surgery* 50: 309-314, 1960.
- Erdahagi, M., Eckstein, H.B. and Crome, L.: *Pulmonary embolisation as a complication of ventriculo-atrial shunts inserted for hydrocephalus.* *Develop. Med. Child. Neural Supp.* 11:36-44, 1966.
- Ferguson, A.H.: *Intraperitoneal diversion of the cerebro-spinal fluid in cases of hydrocephalus.* (Review) *N.Y. Medical Journal* 67:902, 1898. Fischer, E.G. and Shillito, J., Jr.: *Large abdominal cysts: a complication of peritoneal shunts. Report of three cases.* *J. Neurosurgery* 31:441-444, 1969.
- Hammon, W.M.: *Evaluation and use of the ventriculo-peritoneal shunt in hydrocephalus.* *J. Neurosurgery* 34:792-795, 1971.
- Harsh, G.R.: *Peritoneal shunt for hydrocephalus utilizing the fimbria of the fallopian tubes for entrance to the peritoneal cavity.* *J. Neurosurgery* 11:284-294, 1954.
- Illingworth, R.D.: *Subdural hematoma after the treatment of chronic hydrocephalus by ventriculo-caval shunts.* *J. Neural., Neurosurgery, Psychiatry* 33:95-99, 1970.
- Illingworth, R.D., Logue, V., Symon, L. and Uemura, K.: *The ventriculocaval shunt in the treatment of adult hydrocephalus: results and complications in 101 patients.* *J. Neurosurgery* 35:681-685, 1971.
- Ingram, F.D., Alexander, E. and Matron, D.D.: *Polyethylene, a new synthetic plastic for use in surgery: experimental applications in neuro-surgery.* *J.A.M.A.* 35:82-87, 1947.
- Irving, M.L., Costello, P., Hail, G.E. and Richham, P.P.: *Tissue reaction to peritoneal silastic.* *J. Pediatric Surg.* 5:724, 1971.
- Jackson, I.J. and Snodgrass, S.R.: *Peritoneal shunts in the treatment of hydrocephalus and increased intracranial pressure: a 4-year survey of 62 patients.* *J. Neurosurgery* 12:216-222, 1955.
- Kloss, J.L.: *Craniosynostosis secondary to ventriculo-atrial shunt.* *Am. J. Dis. Child* 116: 315-317, 1968.
- Long, D.M., DeWall, R.A. and French, L.A.: *Unusual complication of ventriculoauricular shunt: a report of two cases.* *J. Neurosurgery* 21:233-234, 1964.
- Matson, D.D.: *Hydrocephalus treated by arachnoid-ureterostomy: report of 50 cases.* *Pediatrics* 12:326-334, 1953.
- Murtagh, F. and Lehman, R.: *Peritoneal shunts in the management of hydrocephalus.* *J.A.M.A.* 202:1010-1014, 1967.
- Nugent, G.R., Lucas, R. and Judy, M. et al.: *Thrombo-embolic complications of ventriculo-atrial shunts; angiocardigraphic and pathologic correlations.* *J. Neurosurgery* 24:34-42, 1966.
- Nulsen, F.E. and Spitz, E.B.: *Treatment of hydrocephalus by direct shunt from ventricle to jugular vein.* *Surg. Forum* 2:399-403, 1952.
- Overton, M.C. and Snodgrass, S.R.: *Ventriculo-venous shunt for infantile hydrocephalus: a review of five years experience with their method.* *J. Neurosurgery* 23:517-521, 1965.
- Patel, C.P. and Matloub, H.: *Vaginal perforation as a complication of ventriculo-peritoneal shunt.* *J. Neurosurgery* 38:761-762, 1973.
- Provenzano, R.W., Wetterlow, B.S. and Sullivan, C.L.: *Immunization and antibody response*

- in the newborn infant. New England J. of Med.* 273:956-965, 1965.
- Pudenz, R.H. and Russell, F.E. *et al.*: *Ventriculo-auriculostomy: a technique for shunting cerebro-spinal fluid into the right auricle. Preliminary report. J. Neurosurgery* 14: 171-179, 1957.
- Raimondi, A.J. and Matsumoto, S.A.: *A simplified technique for performing the ventriculo-peritoneal shunt. J. Neurosurgery* 26: 357-366, 1967.
- Ramani, P.S.: *Extrusion of abdominal catheter of ventriculo-peritoneal shunt into the scrotum. Case report. J. Neurosurgery* 40(6): 772-773, June 1974.
- Rosen, F.S. and Janeway, C.A.: *Immunological competence of the newborn infant. Pediatrics* 33:159-160, 1964.
- Rosenthal, J.D., Golden, G.T., Shaw, C.A. and Janes, J.A.: *Intractable ascites: a complication of ventriculo-peritoneal shunting with a silastic catheter. Amer. J. Surg.* 5:613-614, May 1974.
- Schinke, R.T., Block, P.H. and Mark, V.H., *et al.*: *Indolent staphylococcus albus and aureus bacterimia after ventriculo-atrialostomy: role of foreign body in its initiation and perpetuation. New England J. Med.* 264: 264-270, 1961.
- Shurtleff, D.B., Christie, D. and Foltz, E.L.: *Ventriculoauriculostomy-associated infection: a 12 year study. J. Neurosurgery* 35:686-693, 1971.
- Sperling, D.R., Patrick, J.R. and Anderson, F.M. *et al.*: *Cor pulmonale secondary to ventriculoauriculostomy. Amer. J. Dis. Child.* 107:308-315, 1964.
- Strenger, L.: *Complications of ventriculo-venous shunts. J. Neurosurgery* 20:219-224, 1963.
- Washburn, T.C., Medearis, D.N. and Childs, B.: *Sex differences in susceptibility to infections. Pediatrics* 35:57-64, 1965.