Technical Note

Shunt implantations and peritoneal catheters: Do not cut beyond 20 cm

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Abstract

Background: Ventriculoperitoneal shunts are supplied with long peritoneal catheters, most commonly between 80 and 120 cm long. ISO/DIS 7197/2006[15] shunt manufacturing procedures include peritoneal catheter as an integrate of the total resistance. Cutting pieces of peritoneal catheters upon shunt implantation or revision is a common procedure.

Methods: We evaluated five shunts assembled with different total pressure resistances and variable peritoneal catheter lengths in order to clarify the changes that occurred in the hydrodynamic profile when peritoneal catheters were cut upon shunt implantation or shunt revision.

Results: Originally, all shunts performed within the operational range. Shunt 1 performed in a lower pressure range at 200 mm cut off peritoneal catheter and as a low-pressure shunt with –300 mm cut off. Shunt 2 was manufactured to run at the higher border pressure range, and it went out of specification with a 300 mm cut off. Shunt 3 was manufactured to run close to the lower border pressure range, and at 100 mm cutoff, it was already borderline in a lower resistive category. Other shunts also responded similarly.

Conclusion: The limit to maintain a shunt in its original pressure settings was 20 cm peritoneal catheter cutting length. By cutting longer pieces of peritoneal catheter, one would submit patients to a less-resistive regimen than intended and his reasoning will be compromised. The pediatric population is more prone to suffer from the consequences of cutting catheters. Shunt manufacturers should consider adopting peritoneal catheters according to the age (height) of the patient.

Key Words: Hydrocephalus, shunt hydrodynamics, shunt overdrainage

INTRODUCTION

Neurosurgeons routinely cut off pieces of the peritoneal catheter upon shunt implantation/revision, and this occurs more frequently in the pediatric and newborn population due obviously to the height of the patients. In a previous work,[17] we have demonstrated that small changes either in diameter or length of original peritoneal catheters compromise the resistive effect of the shunt assembly. Shunt selection was at random, and we tested adult-type, high- and medium-pressure shunts.[17] Cutting off pieces of the peritoneal catheter lowered shunt resistance and shunts operated in a lower pressure range. Also, changes in internal diameter (i.d.) as small as 0.1 mm lowered or increased shunt resistance, depending on original diameter. The surgical maneuver of cutting off a piece of the peritoneal catheter upon shunt implantation may be even more critical in pediatric and newborn patients. In this paper, we further explored the relationship of different neonatal shunt pressure settings as compared with different peritoneal catheter lengths, in an attempt to quantify the relative responsibility of the peritoneal catheter in the total shunt pressure assembly, and if there is a specific peritoneal cutting length limit which neurosurgeons should respect in order to maintain the original shunt-resistive specifications and not to potentialize shunt overdrainage.

MATERIALS AND METHODS

Five pediatric shunt systems with different pressure settings were submitted to hydraulic forces in a rig according to ISO/DIS 7197 standard for 50, 40, 30, 20, 10, and 5 ml/h flow. The rig has been described in detail in previous publications[11,12,17] Results are the average flow for three events. Shunt's hydrodynamic properties were measured on their original assemblies and then pieces of catheters were cut off by 100 mm down to 500 mm length. For each 100 mm peritoneal catheter cut, bench tests were repeated. Decimals were discarded. All shunts had peritoneal catheter with i.d. 1.2 mm. In the manufacturing process, the silicone-resistive component in the valve assembly was prepared to add increased resistance to compensate the losses of a smaller peritoneal catheter as it had been cut. Shunt 1 was manufactured as neonatal medium-pressure range shunt with 1000 mm peritoneal catheter. Shunt 2 was manufactured as neonatal low-pressure shunt at the upper pressure range border with 1000 mm peritoneal catheter. Shunt 3 was manufactured as neonatal low-pressure shunt at average pressure range with 1000 mm peritoneal catheter. Shunt 4 was manufactured as neonatal low-pressure shunt at average pressure range with 800 mm peritoneal catheter. Shunt 5 was manufactured as neonatal low-pressure shunt at average pressure range with 700 mm peritoneal catheter. Additionally, the individual resistances of ventricular and peritoneal catheters were measured.

RESULTS

Shunt 1, neonatal medium-pressure valve at average range [Figure 1a, b; Table 1]: Performed at a pressure of 121, 107, 90, 74, 66, and 54 mmH$_2$O for original catheter length of 1.000 mm for 50, 40, 30, 20, 10, and 5 ml/h flow, respectively; performed at a pressure of 109, 93, 82, 69, 56, and 51 mmH$_2$O for 900 mm catheter length for 50, 40, 30, 20, 10, and 5 ml/h flow, respectively; performed at a pressure of 100, 81, 72, 62, 51, and 45 mmH$_2$O for 800 mm catheter length for 50, 40, 30, 20, 10, and 5 ml/h flow, respectively; performed at a pressure of 92, 77, 62, 54, 45, and 37 mmH$_2$O for 700 mm catheter length for 50, 40, 30, 20, 10, and 5 ml/h flow, respectively; performed at a pressure of 85, 72, 67, 48, 38, and 33 mmH$_2$O for 600 mm catheter length for 50, 40, 30, 20, 10, and 5 ml/h flow, respectively; performed at a pressure of 82, 71, 56, 44, 35, and 29 mmH$_2$O for 500 mm catheter length for 50, 40, 30, 20, 10, and 5 ml/h flow, respectively.
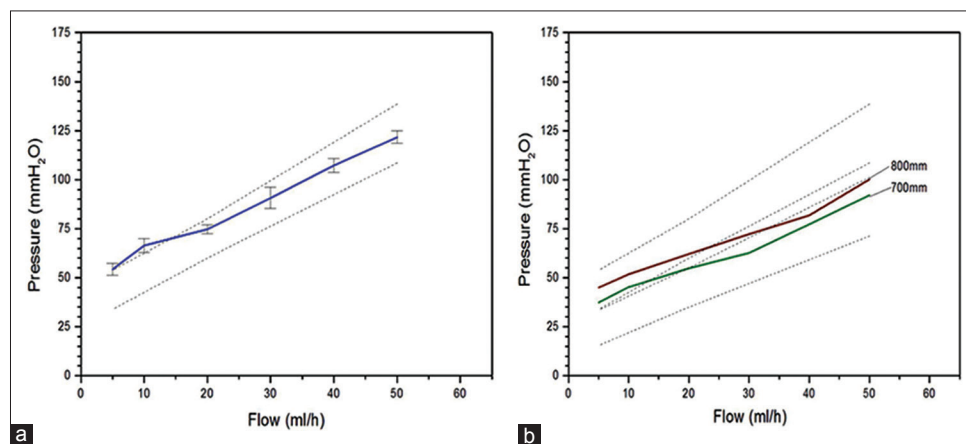

Figure 1: Shunt 1: (a) Neonatal medium-pressure shunt assembly at average range with 1000 mm peritoneal catheter; (b) same shunt as Figure 1a with peritoneal catheter pieces cut off at −20 cm and −30 cm. Neonatal medium-pressure shunt assembly at average range with 1000 mm peritoneal catheter

Shunt 2, neonatal low-pressure calibrated at upper border range [Figure 2a, b; Table 2]: Performed at a pressure of 105, 82, 70, 52, 42, and 35 mmH2O for original catheter length of 1.000 mm for 50, 40, 30, 20, 10, and 5 ml/h flow, respectively; performed at a pressure of 87, 70, 58, 47, 35, and 30 mmH2O for 900 mm catheter length for 50, 40, 30, 20, 10, and 5 ml/h flow, respectively; performed at a pressure of 76, 65, 53, 41, 30, and 26 mmH2O for 800 mm catheter length for 50, 40, 30, 20, 10, and 5 ml/h flow, respectively; performed at a pressure of 69, 59, 43, 34, 27, and 22 mmH$_2$O for 700 mm catheter length for 50, 40, 30, 20, 10, and 5 ml/h flow, respectively; performed at a pressure of 59, 50, 37, 29, 23, and 18 mmH$_2$O for 600 mm catheter length for 50, 40, 30, 20, 10, and 5 ml/h flow, respectively.

Shunt 3, neonatal low-pressure calibrated at average range [Figure 3a, b; Table 3]: Performed at a pressure of 84, 72, 58, 40, 31, and 24 mmH$_2$O for original catheter length of 1.000 mm for 50, 40, 30, 20, 10, and 5 ml/h flow, respectively; performed at a flow 69, 59, 44, 35, 27, and 22 mmH$_2$O for 900 mm catheter length for 50, 40, 30, 20,

Table 1: Neonatal medium-pressure shunt test at average range with Ø= 1.2 mm and L=1000 mm peritoneal catheter

Flow (ml/h)	Tests			Average	Standard deviation
	1	2	3		
L=1000 mm peritoneal catheter					
50	121	119	125	121.7	3.1
40	104	107	111	107.3	3.5
30	85	91	96	90.7	5.5
20	76	72	76	74.7	2.3
10	70	63	66	66.3	3.5
5	57	51	55	54.3	3.1
L=800 mm peritoneal catheter					
50	98	104	99	100.3	3.2
40	81	86	78	81.7	4
30	72	76	69	72.3	3.5
20	64	59	63	62	2.6
10	51	49	55	51.7	3.1
5	45	43	47	45	2
L=700 mm peritoneal catheter					
50	90	94	92	92	2
40	80	75	77	77.3	2.5
30	64	62	62	62.7	1.2
20	55	52	57	54.7	2.5
10	48	43	45	45.3	2.5
5	40	35	37	37.3	2.5

Table 2: Neonatal medium-pressure shunt test at average range with Ø= 1.2 mm and L=1000 mm peritoneal catheter

| Flow (ml/h)	Tests			Average	Standard deviation
	1	2	3		
L=1000 mm peritoneal catheter					
50	101	107	108	105.3	3.8
40	79	83	85	82.3	3.1
30	69	67	75	70.3	4.2
20	54	50	53	52.3	2.1
10	43	39	45	42.3	3.1
5	37	33	37	35.7	2.3
L=800 mm peritoneal catheter					
50	78	77	74	76.3	2.1
40	62	66	67	65	2.6
30	53	52	55	53.3	1.5
20	40	42	41	41	1
10	29	33	30	30.7	2.1
5	26	27	25	26	1
L=700 mm peritoneal catheter					
50	69	73	67	69.7	3.1
40	60	61	57	59.3	2.1
30	44	43	42	43	1
20	32	36	34	34	2
10	26	30	26	27.3	2.3
5	22	24	20	22	2
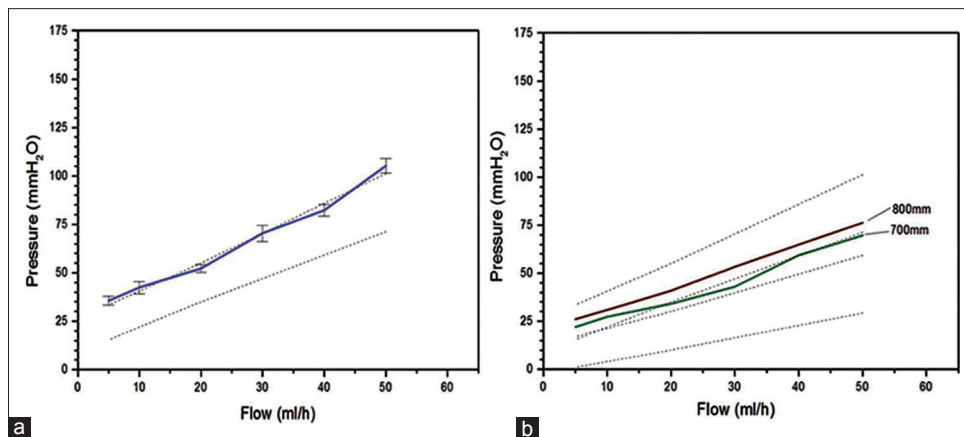
Figure 2: Shunt 2: (a) Neonatal low-pressure shunt assembly at high-pressure range with 1000 mm peritoneal catheter; (b) same shunt as Figure 2a with peritoneal catheter pieces cut off at −20 cm and −30 cm. Low-pressure shunt assembly at average range with 1000 mm peritoneal catheter

10, and 5 ml/h flow, respectively; performed at a pressure of 60, 50, 38, 30, 25, and 19 mmH$_2$O for 800 mm catheter length for 50, 40, 30, 20, 10, and 5 ml/h flow, respectively; performed at a pressure of 52, 44, 35, 26, 21 and 17 mmH$_2$O for 700 mm catheter length for 50, 40, 30, 20, 10, and 5 ml/h flow, respectively; performed at a pressure of 46, 39, 31, 25, 20, and 17 mmH$_2$O for 600 mm catheter length for 50, 40, 30, 20, 10, and 5 ml/h flow, respectively.

Shunt 4, neonatal low-pressure calibrated at average range for 800 mm peritoneal catheter [Figure 4a, b; Table 4]: Performed at a pressure of 97, 75, 65, 47, 36, and 31 mmH2O for original catheter length of 800 mm for 50, 40, 30, 20, 10, and 5 ml/h flow, respectively; performed at a pressure of 82, 67, 52, 41, 32, and 27 mmH$_2$O for 700 mm catheter length for 50, 40, 30, 20, 10, and 5 ml/h flow, respectively; performed at a pressure of 71, 60, 50,

Table 3: Neonatal low-pressure shunt test at average pressure range with Ø= 1.2 mm and L=1000 mm peritoneal catheter

Flow (ml/h)	Tests			Average	Standard deviation
	1	2	3		
L=1000 mm peritoneal catheter					
50	84	88	81	84.3	3.5
40	73	75	69	72.3	3.1
30	58	60	56	58	2
20	40	43	39	40.7	2.1
10	31	30	32	31	1
5	24	23	26	24.3	1.5
L=900 mm peritoneal catheter					
50	69	73	67	69.7	3.1
40	60	61	57	59.3	2.1
30	47	43	44	44.7	2.1
20	35	36	34	35	1
10	26	30	26	27.3	2.3
5	22	24	20	22	2
L=800 mm peritoneal catheter					
50	62	60	59	60.3	1.5
40	49	53	50	50.7	2.1
30	37	40	38	38.3	1.5
20	30	33	29	30.7	2.1
10	25	26	24	25	1
5	19	20	18	19	1

Table 4: Neonatal low-pressure shunt test at average pressure range with Ø= 1.2 mm and L=800 mm peritoneal catheter

| Flow (ml/h)	Tests			Average	Standard deviation
	1	2	3		
L=800 mm peritoneal catheter					
50	98	95	99	97.3	2,1
40	78	72	75	75	3
30	65	64	68	65.7	2.1
20	47	49	46	47.3	1.5
10	34	39	35	36	2.6
5	30	33	31	31.3	1.5
L=600 mm peritoneal catheter					
50	68	71	74	71	3
40	55	60	67	60.7	6
30	46	52	53	50.3	3.8
20	36	35	38	36.3	1.5
10	29	29	30	29.3	0.6
5	25	23	24	24	1
L=500 mm peritoneal catheter					
50	65	63	67	65	2
40	54	55	57	55.3	1.5
30	42	40	43	41.7	1.5
20	30	31	34	31.7	2.1
10	25	27	26	26	1
5	21	23	20	21.3	1.5
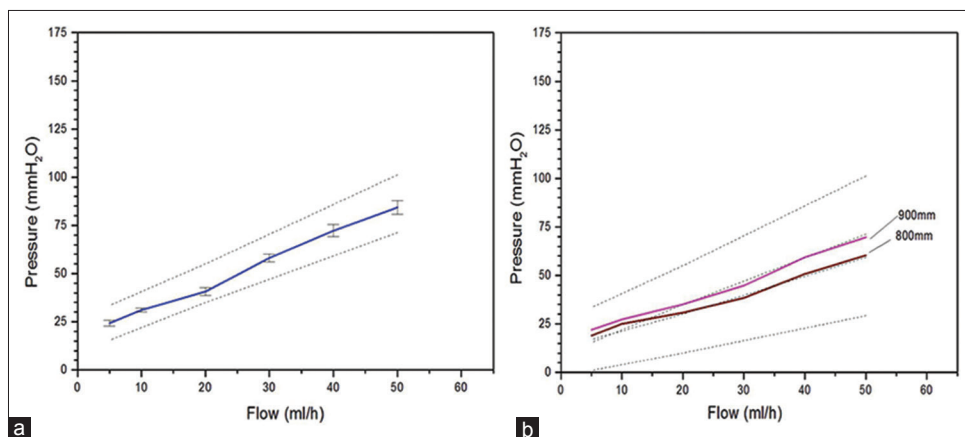
Figure 3: Shunt 3: (a) Neonatal low-pressure shunt assembly at average pressure range with 1000 mm peritoneal catheter; **(b)** same shunt as Figure 3a with peritoneal catheter pieces cut off at −10 cm and −20 cm. Low-pressure shunt assembly at average range with 1000 mm peritoneal catheter

36, 29, and 24 mmH$_2$O for 600 mm catheter length for 50, 40, 30, 20, 10, and 5 ml/h flow, respectively; performed at a pressure of 65, 55, 41, 31, 26, and 21 mmH$_2$O for 500 mm catheter length for 50, 40, 30, 20, 10, and 5 ml/h flow, respectively.

Shunt 5, neonatal low-pressure calibrated at average range for 700 mm peritoneal catheter [Figure 5a, b; Table 5]: Performed at a pressure of 84, 73, 58, 46, 36, and 31 mmH$_2$O for original catheter length of 700 mm for 50, 40, 30, 20, 10, and 5 ml/h flow, respectively; performed at a pressure of 75, 61, 51, 40, 33, and 28 mmH$_2$O for 600 mm catheter length for 50, 40, 30, 20, 10, and 5 ml/h flow, respectively; performed at a pressure of 67, 57, 45, 35, 29, and 24 mmH$_2$O for 500 mm catheter length for 50, 40, 30, 20, 10, and 5 ml/h flow, respectively.

Graphs in Figures 1 and 5 provide a paired, easy visual identification of each shunt's performance in its original assembly and with cut-down peritoneal catheters. Due to the proximity of curves, and for a better visualization, we plotted only the curves that were in the limit of each shunt specification and also discarded the standard deviation. Table 1 provides detailed information for each one of the three events of each shunt assembly, the average value and standard deviation.

All shunts performed within the operational range in their original assemblies. Shunt 1 performed in a lower pressure range, i.e. −200 mm cut off peritoneal catheter, and as a low-pressure shunt, i.e. with a −300 mm cut off. Shunt 2 was manufactured to run at the higher border pressure range to the maximum possible, and it went out of specification with a −300 mm cut off. Shunt 3 was manufactured to run close to the lower border pressure range, and at −100 mm cut off, it was already borderline and with −200 mm cut off, it was definitively in a lower resistive category. Again, shunts 4 and 5 were in a lower resistive category at −200 mm cut off despite their different original peritoneal catheter lengths at the shunt assembly.
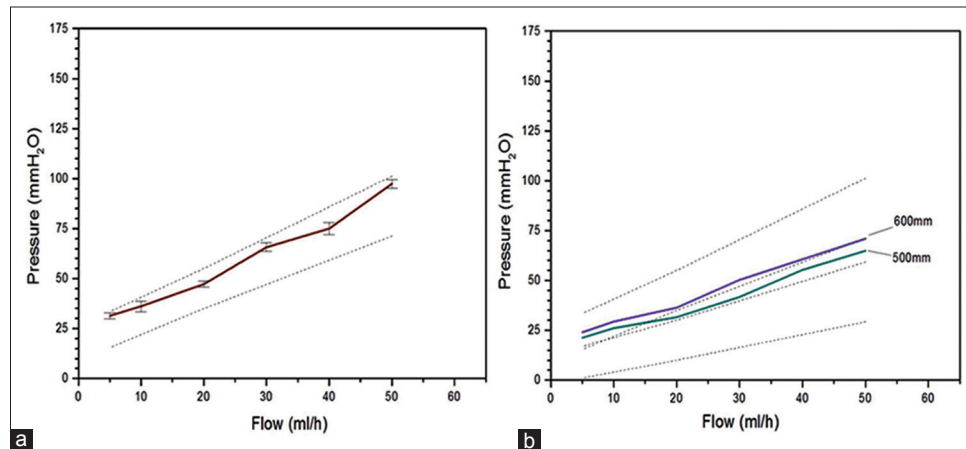

Figure 4: Shunt 4: (a) Neonatal low-pressure shunt assembly at average pressure range with 800 mm peritoneal catheter; **(b)** same shunt as Figure 4a with cut off peritoneal catheter pieces at −10 cm and −20 cm. Low-pressure shunt assembly at average range with 1000 mm peritoneal catheter
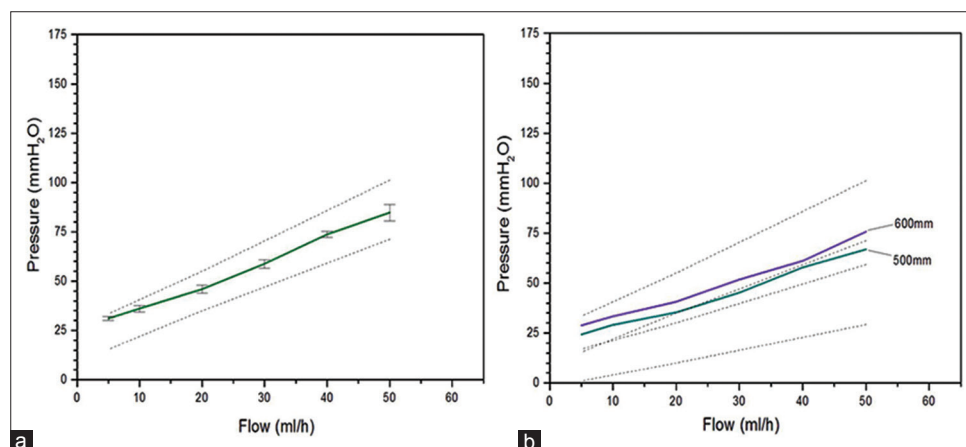

Figure 5: Shunt 5: (a) Neonatal low-pressure shunt assembly at average pressure range with 700 mm peritoneal catheter; **(b)** same shunt as Figure 5a with peritoneal catheter pieces cut off at −10 cm and −20 cm. Low-pressure shunt assembly at average range with 1000 mm peritoneal catheter

Table 5: Neonatal low-pressure shunt test at average pressure range with Ø=1.2 mm and L=700 mm peritoneal catheter

Flow (ml/h)	Tests			Average	Standard deviation
	1	2	3		
L=700 mm peritoneal catheter					
50	86	80	88	84.7	4.2
40	74	72	75	73.7	1.5
30	58	61	57	58.7	2.1
20	48	46	44	46	2
10	37	37	34	36	1.7
5	30	32	31	31	1
L=600 mm peritoneal catheter					
50	77	75	75	75.7	1.2
40	64	62	57	61	3.6
30	55	50	50	51.7	2.9
20	42	41	39	40.7	1.5
10	34	35	31	33.3	2.1
5	28	30	28	28.7	1.2
L=500 mm peritoneal catheter					
50	67	65	69	67	2
40	55	58	60	57.7	2.5
30	43	45	48	45.3	2.5
20	33	35	38	35.3	2.5
10	27	29	31	29	2
5	23	24	26	24.3	1.5

DISCUSSION

Hydraulic disturbances are common after shunt implantation,[13,16] and overdrainage is invariably associated with gravity. de Jong *et al.*[6] alternatively hypothesized that rather being caused by siphoning in upright position, overdrainage occurred while patients were lying down, due to fluctuations of cerebral blood volume (CBV). A temporary increase in CBV causes both compensatory cerebrospinal fluid (CSF) displacements from the brain to the spinal compartment and through the shunt. The loss of CSF would depend on valve characteristics and the amplitude and duration of CBV. In the same group of patients,[10] low-pressure valves resulted in a significantly higher incidence of subdural hygromas, compared with medium-high pressure valves.

There are many publications describing the physical variables involved in the shunt functionality[3,9]. Fox *et al.*[8,9] described those variables according to Equation (1):

$$PP = VFP + HP - (DCP + CP) \tag{1}$$

where PP is the perfusion pressure through a shunt, VFP the intraventricular pressure, HP the hydrostatic pressure of the distal catheter, DCP the distal cavity pressure (in the right atrium or abdomen), and CP is the closing

pressure of the valve, which ultimately is an expression of the resistance of the whole shunt assembly. CP is also known as "working pressure" or "performance level" of the valve. CP is submitted to Poiseuille's law, expressed mathematically as Equation (2):

$$R = 8\eta L/\pi r^4 \tag{2}$$

where η is the viscosity (in centipoise), L the tubing length (in mm), and r the radius of the tubing. Thus, the peritoneal catheter tubing length (L) and the viscosity (η) of fluid within the tubing directly influence the shunt resistance to CSF flow, while the radius of the tubing influences the shunt resistance exponentially and inversely at the 4th potency. The flow (Q) is related to resistance as shown in Equation (3):

$$Q = PP/R_o \tag{3}$$

where Q is flow and R_o is the shunt resistance to changes in flow rate.

According to ISO7197/2006[15] standards, the pressure of a shunt is given by the resistance of the whole shunt assembly, which obviously includes both the proximal and distal catheters, and it must be considered by the shunt manufacturer. There is enough evidence in the literature emphasizing the important role of the peritoneal catheter[10,14,16] as a resistor element. The importance of the tubing in the whole shunt assembly was addressed by Aschoff *et al.*[1,2] as follows: "When vertical body position is simulated, conventional differential pressure valves show an absolutely unphysiological flow, which is 2-170 times the normal liquor production rate. Although this is compensated in part by the resistance of the silicon tubes, which may produce up to 94% of the resistance of the complete shunt system, a negative intracranial pressure (ICP) of up to 30-44 cm H_2O is an unavoidable consequence, which can be followed by subdural haematomas, slit ventricles, and other well-known complications." Czosnyka *et al.*[4,5] compared the resistance profile of the valve alone and the resistance of the total shunt assembly. According to them, a standard catheter of 1.2 mm i.d. and 90-1200 mm length has a resistance around 2.2 mmHg/ml/min up to 2.6 mmHg/ml/min per 1 m length, and the resistance increases up to 50-80% for a valve. Although the peritoneal catheter takes a considerable share of the total shunt assembly resistance, using or not using a distal catheter is not an issue, since it is required in all shunts. This paper approaches the same issue from a practical, clinical perspective, that is, whether the operational pressure range of a shunt is affected or not when neurosurgeons decrease the length of the peritoneal catheter by cutting it to adapt it to the height or body mass of an individual patient; if it does affect, what is the repercussion to the shunt hydrodynamics when different lengths of the residual catheter are left connected to the shunt assembly and also what would be the behavior of different pressure

setting shunt assemblies when the distal catheter is cut down?

As can be seen in Figures 1-5 and Table 1, regardless of the initial shunt pressure range, all shunts lost resistance as catheters were cut, even at lengths as small as 100 mm. Shunt 1 lost resistance and went out of specification at −200 mm catheter length, and definitively became a low-pressure shunt at −300 mm catheter length. Shunts 2 and 3 are examples of shunts tagged as low-pressure range, but we wanted to explore the extremes of the pressure range of the same shunt assembly. Thus, shunt 2 was manufactured to be at the highest possible level of the specified pressure range, and this shunt tolerated only up to −200 mm smaller peritoneal catheter. At −300 mm peritoneal catheter, it ran out of specification. However, shunt 3, manufactured with a profile close to the average pressure range, tolerated only −100 mm. At −200 mm, the shunt assembly was already performing at the upper border of a very low-pressure shunt. Since all shunt components work as a serial resistance, the smaller lengths of the peritoneal catheter for shunts 4 and 5 were compensated by increasing the resistance in the resistive element of the valve. Whichever was either the length of the peritoneal catheter or the pressure for the initial shunt assembly, they behaved similarly among themselves: At −200 mm length, they were about to get out of specification.

Therefore, cutting 200 mm from the peritoneal catheter brought most of the shunts to the limit of the specified pressure range and cutting 300 mm definitively altered the hydrodynamic profile of any shunt tested, at any pressure and with any catheter length. Thus, 200 mm length seems to be the "safe" length limit to be cut in a peritoneal catheter in order to maintain a shunt in its original operational range.

Therefore, component changes which do not respect shunt original dimensions compromise the shunt hydraulic regimen intended by the neurosurgeon for a specific hydrocephalus shunt implant; for revisions, it may affect the hydraulic stability that the patient may have already reached/adapted himself. The fact is that the patient is submitted to a chronic overdrainage and lower pressure status than one would expect, which contributes to the well-known symptoms and signs mentioned by Aschoff et al.,[1] and may be also the cause of hydraulic decomposition after the implant. This situation is even more important in the pediatric population in which low-pressures valves are more likely to be used.

The utilization of the same dimensions of ventricular and peritoneal catheters for low-pressure shunts and medium- and high-pressure shunts in adults and children is a common attitude among manufacturers. This attitude exacerbates the imbalance in shunt characteristics in the pediatric population in which low-pressure valves are more likely to be used. The relative resistance responsibility of the peritoneal catheter is exacerbated in low-pressure shunts, more commonly used in infants and children, exemplifying:

$$\text{Sum R} = \text{R1} + \text{R2} + \text{R3} \qquad (4)$$

where Sum R is the total shunt resistance, R1 the ventricular catheter resistance, R2 the valve unit resistance, and R3 is the peritoneal catheter resistance. In our tests, individualized average result for $R1 = 12$ mmH$_2$O and the individualized average for $R3 = 28$ mmH$_2$O at 20 ml/h (results not shown). This means that for a medium-pressure shunt (such as 80 mmH$_2$O), we would have

$$80 = 12 + R2 + 28$$

Thus, the estimated valve unit resistance should be pre-set at 40 mmH$_2$O, which represents 50% of the total shunt assembly. The peritoneal catheter would represent 35% of the total shunt assembly. However, for a low-pressure shunt (such as 45 mmH$_2$O) we would have

$$45 = 12 + R2 + 28$$

Thus, valve unit resistance should be pre-set at 5 mmH$_2$O, which represents only 11% of the total shunt assembly. In this hypothetic situation, the peritoneal catheter would represent now 62% of the total shunt resistance. The lower the total shunt assembly pressure, the higher the relative responsibility of the peritoneal catheter. Therefore, the act of cutting off the peritoneal catheter is potentially more harmful to the pediatric population than to the adult population. We also must consider that the population of patients will grow, thus potentializing the hydraulic effect.

The operational range for each pressure shunt of this shunt manufacturer is relatively small; there are other manufacturers with a wider operational range, and the lengths would not necessarily apply to them. Still, this does not eliminate the fact that all first-generation shunts are exposed to the physical effects mentioned above, and they should impact approximately the same absolute values.

Also, rig tests are made in a horizontal position, and it is known that shunts not equipped with an anti-gravitational device or siphon control mechanism are strongly affected by the negative outlet pressure. Siphoning (−23 mmHg according to ISO standards) increases dramatically the drainage rate (>1 ml/min). The surgical maneuver of cutting down the peritoneal catheter potentializes the negative outlet pressure by decreasing CP in Equation (1). Overdrainage and associated subdural hygromas are generally considered to be caused by hydrostatically increased flow through the shunt in the upright position, which is in turn caused by increased negative hydrostatic pressure in the distal catheter.[3,7]

CONCLUSION

We advise not to cut more than 20 cm of the peritoneal catheter as this changes the shunt resistance in a major way to maintain a shunt in its original pressure settings. By cutting longer pieces of peritoneal catheter, one would submit patients to a less-resistive shunt than intended and their reasoning will be compromised; medium and long-term patient submission to a low operational pressure range may be an adjunctive to favor overdrainage. The pediatric population is more prone to suffer the effects of inadvertent peritoneal catheter shortening upon shunt implantation. Shunt manufacturers should consider adopting peritoneal catheters according to the age (height) of the patient.

ACKNOWLEDGMENT

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