Original article

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Pitfalls in Shunting of Hydrocephalus – Clinical Reality and Improvement by the Hydrostatic Dual-Switch Valve

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Summary

The hydrostatic dual-switch valve (DSV) was implanted in 56 patients suffering from hydrocephalus of different causes. Evaluation of the clinical status 3 and 6 months after the operation revealed excellent and good neurological recoveries in the vast majority of cases. Only 7 patients demonstrated an unsatisfactory result according to the grading of *Stein* and *Langfitt*. The CT follow-up, evaluated by the reduction of the *Evans* index, was characterized by only minimal or even no reduction of the ventricular size in more than half of the patients. Only 2 patients of our series developed overdrainage-related problems.

5 cases are presented to illucidate the danger of overdrainage resulting from the implantation of conventional differential-pressure valves, and the possible solution of this problem by hydrostatic devices like the DSV. Our series gives strong evidence, that reestablishing physiological pressure-ranges after shunting is paralleled by a good clinical outcome independent of the ventricular size after shunting.

Key words: Hydrocephalus – Hydrostatic valve – Ventriculo-peritoneal shunt – Overdrainage

Introduction

Although endoscopic IIIrd ventriculostomy as a renewed technology is favoured in an increasing number of institutions, not only for the treatment of occlusive hydrocephalus, but also for patients with communicating hydrocephalus and even slit-ventricle-syndrome (1), the majority of hydrocephalus patients are still treated with valve regulated silastic shunts. But in ventriculo-peritoneal shunting we are still confronted with severe biomechanical problems like overdrainage or clogging of the valve. The implantation of conventional differential-pressure valves is followed by a negative intraventricular pressure in the upright position of the patient (3). The sequela of this overdrainage or so-called siphon-effect are numerous, ranging from the relatively harmless low-intracranial-pressure syndrome to life-threatening complications like upward herniation of the cerebellum. Whereas in children the most feared complication is the slit-ventricle syndrome, the most dangerous sequela in adults is the occurrence of subdural effusions like hygromas or hematomas after shunting (2, 5, 7, 8). Understanding the danger of overdrainage is reflected by the increasing number of new constructions in the third generation of valves now on the market, the so-called hydrostatic devices. Theoretically hydrostatic valves have considerable advantages compared to conventional differential-pressure valves and to the second generation of adjustable or programmable devices, but some of the hydrostatic valves have a tendency to underdrain or to clog. To overcome the problem of overdrainage on the one hand and the danger of blockage of the valve on the other, the new construction principle of the DSV has been developed by biomedical engineers of the Technical University of Berlin in close cooperation with our neurosurgical department (4, 6). Besides the clinical results and the CT follow-up of our 56 cases with DSV we want to present illustrative cases to stress the danger of overdrainage and the importance to reestablish physiological intraventricular pressure ranges after shunting.

Methods

From February 1995 to March 1998 56 patients were provided with the dual-switch valve, the majority of cases were adults with hydrocephalus. 22 male and 33 females received the DSV, the youngest patient was 9 years old, the oldest 82 (mean 53.4). The time of follow-up was from 3 to 40.2 months (mean 28.6). The series comprised 47 cases of normal pressure hydrocephalus (15 idiopathic, 32 secondary NPH following subarachnoid hemorrhage, trauma or major operations). Only 9 cases had hypertensive hydrocephalus of different origin. In 48 cases we implanted the DSV as a primary shunt, in 8 cases the DSV was used as a replacement for previous shunts with various other valves. All the procedures done were ventriculoperitoneal with a frontal burrhole. In all patients the neurological status and CT scanning was assessed prior to shunting, at discharge about 14 days after the operation and again 3 and 6 months after surgery. In this series, with only 2 exceptions, we used dual-switch valves with an opening pressure of 13 cm of water for the recumbent and 40 cm of water for the upright posture of the patient.

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Results

The CT follow-up measured by the regression of the *Evans* index was remarkable in so far as more than half of the patients (35 out of 56) demonstrated only minimal or even no reduction of the ventricular size 6 months after the operation, and 12 others showed only slight regression of the ventricles (Fig. 1). But in the vast majority of the cases no reduction of ventricular size was accompanied by a good or even excellent improvement of the clinical status. The grade of regression of ventricles was in contrast to the resolution of the hydrocephalic dilation of the ventricles in a series of 21 patients who received a conventional differential-pressure valve, demonstrating a much higher reduction of ventricular size than the DSV group (7).

We used several methods to determine the clinical status before and after shunting (grading according to *Stein* and *Langfitt*, *Black* scale, *Barthel* index, *Kiefer* index). The result of the clinical outcome and the grading of the postoperative development of the clinical course in relation to the initial clinical status according to *Stein* and *Langfitt* demonstrate excellent and good results in the vast majority of our cases, in only 7 cases did we see unsatisfactory results (Fig. 2).

In the case who received the DSV as a replacement, the previous valve had to be explanted or the shunt had to be ligated due to severe complications. With the 3 illustrative cases presented here we want to point out the danger of overdrainage and demonstrate the capability of hydrostatic valves to avoid the dangerous sequelae of overdrainage.

Case 1 (Fig. 3a and b): A 66-years-old patient with idiopathic normal-pressure hydrocephalus who was bedridden on admission because of

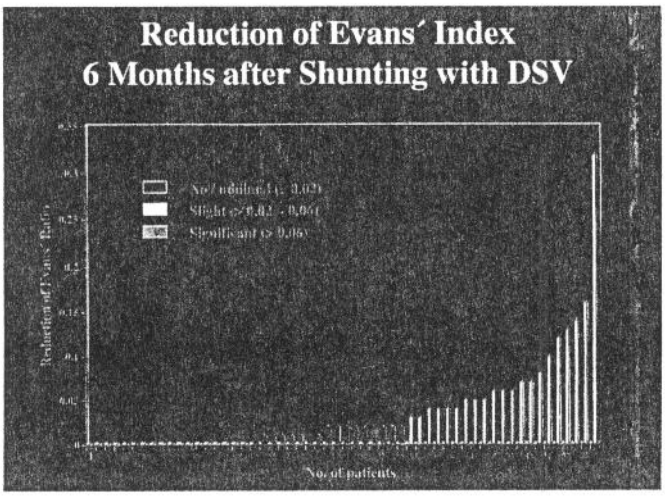

Fig. 1

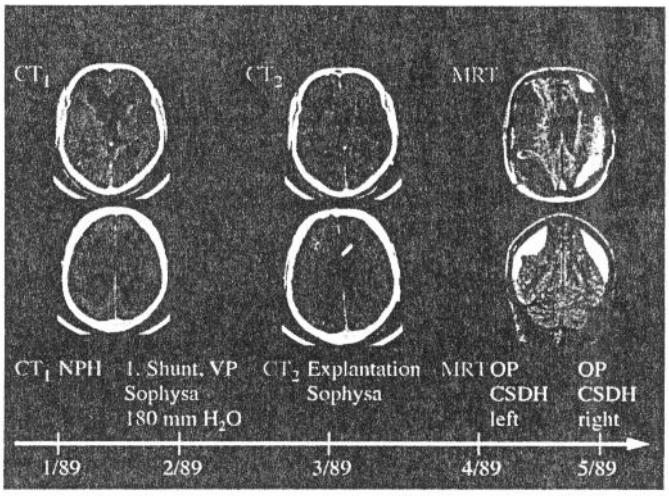

Fig. 3a See Case 1.

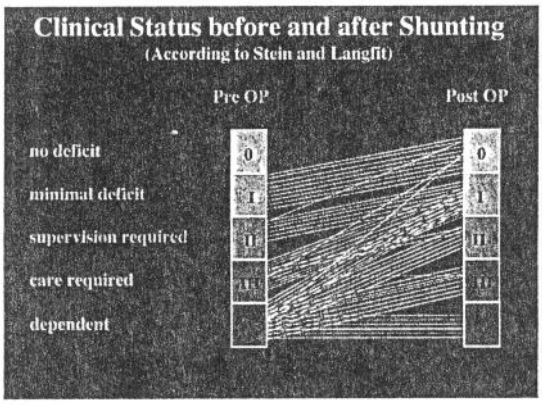

Fig. 2

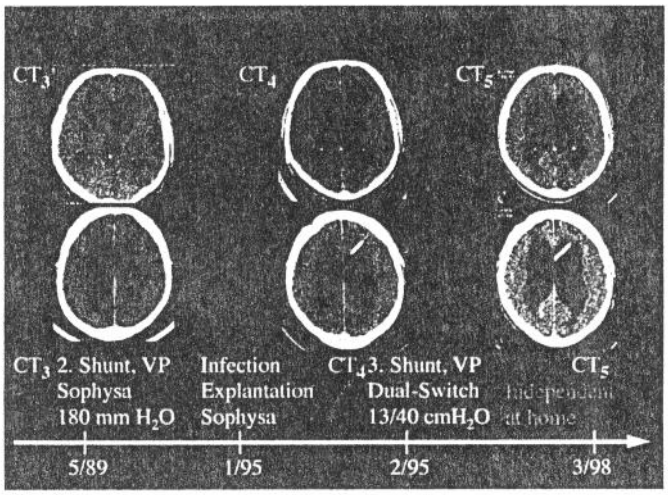

Fig. 3b See Case 1.

severe gait disturbance, nausea, incontinence and severe mnestic deficits. Fig. 3a: In February 1998, the patient received a programmable valve with a high-pressure adjustment. He developed subdural effusions on both sides which progressed despite explantation of the shunt, into chronic subdural hematomas, which had to be evacuated. The evaluation of the explanted device revealed no defect of the valve mechanism (Fig. 3b). Following that regression of the subdural effusions, the ventricles expanded again, accompanied by a deterioration of the clinical status, thus the same valve with the high-pressure adjustment was implanted, followed by a transient improvement of the neurological symptoms. 6 years later the patient became bedridden again and his mental status deteriorated. Because of a questionable local infection, the Sophy-valve had to be explanted again. The patient remained bedridden and the CT follow-up showed further dilatation of the ventricular system. Thus we implanted the dual-switch valve at the beginning of 1995. For 3 years the patient has been independent at home and able to take a walk outside every day, although the CT follow-up scans did not show any reduction of the ventricular size.

Case 2 (Fig. 4a to c): This 60-years-old man suffering from normal-pressure hydrocephalus developed a subdural hematoma after the implantation of a flow-regulated valve at the beginning of 1995 (Fig. 4a). After evacuation of the hematoma and removal of the shunt, he developed dilatation of the ventricles again as shown on the MR scan with typical neurological symptoms and signs. We implanted an adjustable valve, beginning with an opening pressure of 140 mm of water (Fig. 4c). He developed symptomatic hygromas and narrow ventricles. Despite adjusting the valve to the highest possible opening pressure, the hygromas did not resolve and the clinical status deteriorated. Therefore, we had to ligate the shunt. The patient developed a hydrocephalic status again (Fig. 4b). After implantation of the dual-switch valve, he is able to take care of himself independently at home and the radiological follow-up demonstrates the typical minimal reduction of the ventricular size without subdural effusions.

Case 3 (Fig. 5a to e): A 40-years-old female with a juvenile hydrocephalus and putative aqueductal stenosis on MR scan had received 2 different differential-pressure valves in another clinic because of hypertensive hydrocephalus with headache, nausea and vomiting. She came to our department suffering from headache and severe gait disturbance with 2 CT scans (Fig. 5a) clearly demonstrating a distinct enlargement over a period of 2 years. Primarily, a conventional medium-pressure valve was implanted with the sequela of hygromas. Then a programmable valve in the highest possible adjustment was inserted but the subdural hygromas increased in spite of ligation of the shunt (Fig. 5b). She finally developed subdural hematoma which had to be evacuated. Parallel to the resolution of the subdural effusion, the ventricular system expanded and the clinical status deteriorated again, thus we implanted a DSV with an opening pressure of 13 cm of water for the lying and 40 cm H_2O for the standing position. Only one month later CT scans revealed subdural hygromas on both sides (Fig. 5c). This is the only patient in our DSV series with persisting hygromas. We ligated the shunt and looked for reasons of this overdrainage. Finally, we found out, that we had implanted the DSV in too inclined position in the upper part of the barrel shaped thorax of the patient, thus the high pressure chamber could not be activated (Fig. 5d left). Therefore, we corrected the incorrect location of the valve to a more vertical position in the lower thoracic region (Fig. 5d right). This correction and the choice of a higher

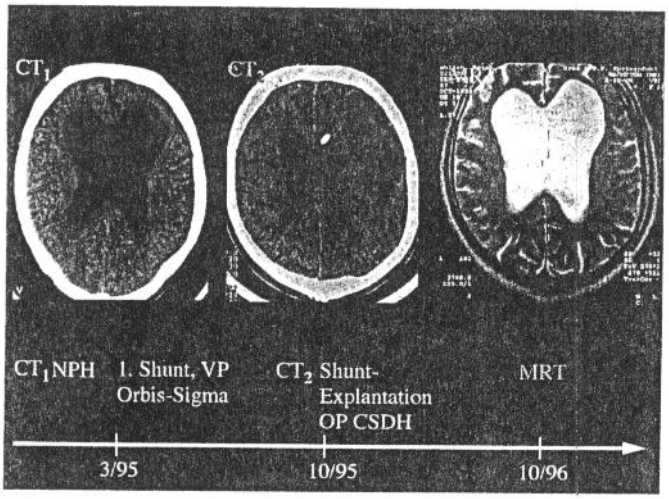

Fig. 4a See Case 2.

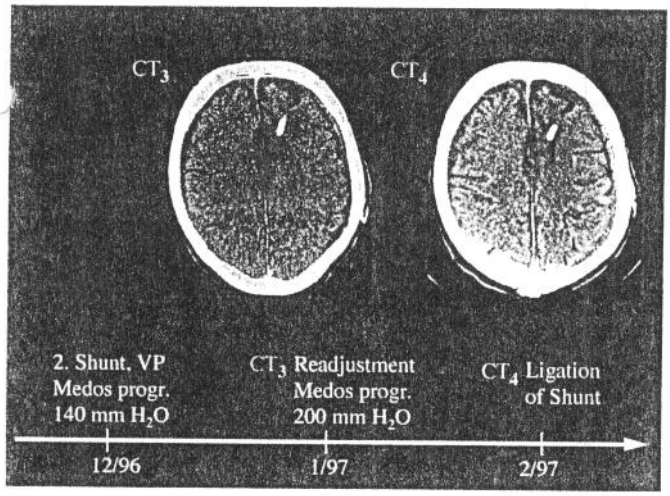

Fig. 4b See Case 2.

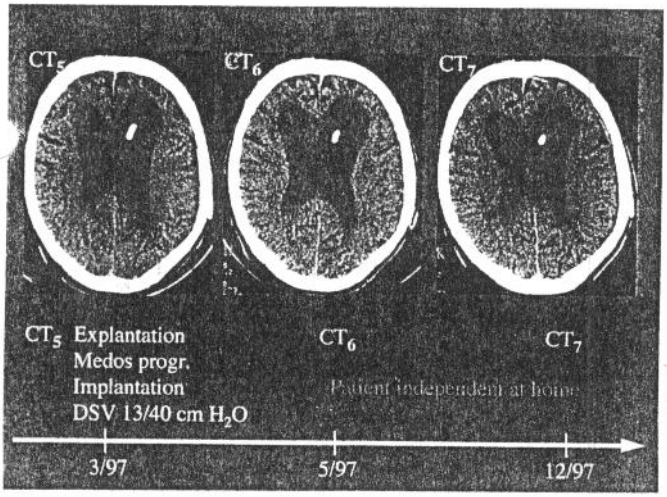

Fig. 4c See Case 2.

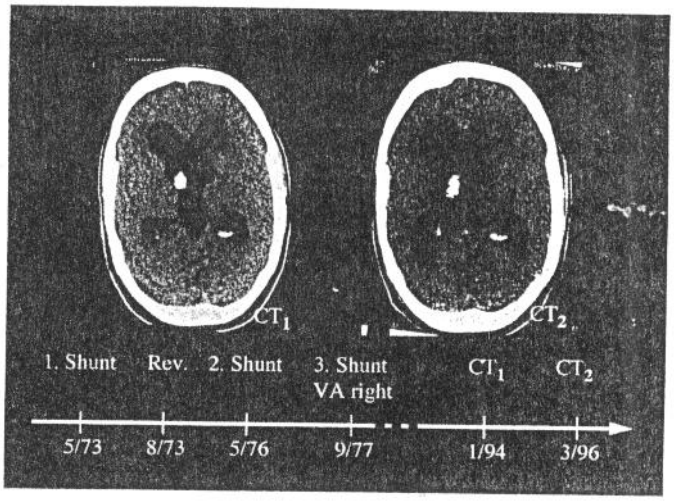

Fig. 5a See Case 3.

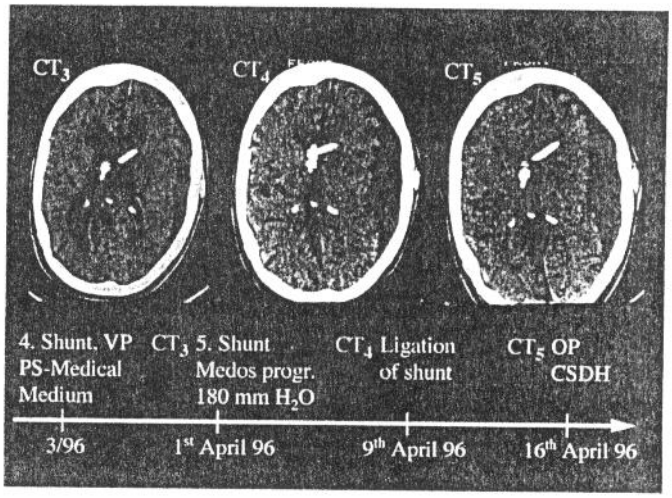

Fig. 5b See Case 3.

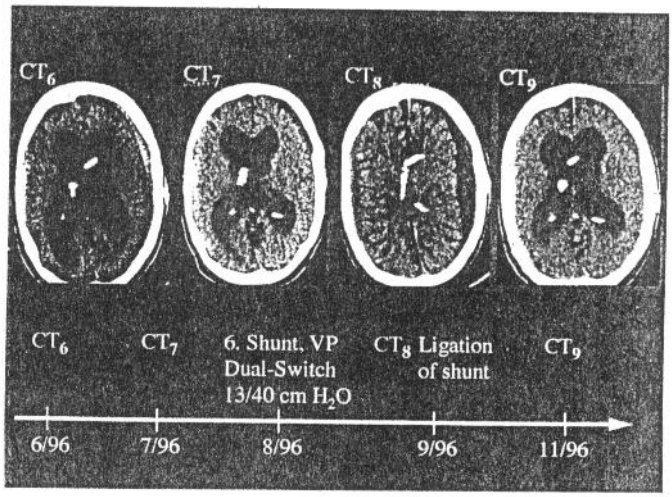

Fig. 5c See Case 3.

opening pressure resulted in an excellent clinical result and the patient was able to take up her job in a post-office again after 3 years of illness due to overdrainage of the shunt (Fig. 5e).

Cases 4 and 5 (Fig. 6a and b): Two patients suffering from hypertensive hydrocephalus due to a partially thrombosed giant aneurysm of the basilar artery were treated with a VP shunt. Whereas the 62-years-old male treated with a DSV had an uneventful postoperative follow-up (Fig. 6a), the 56-years-old female developed a hygroma only 2 days after

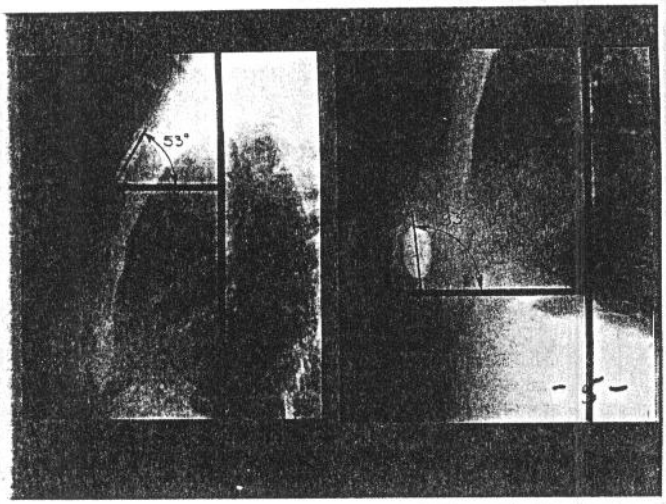

Fig. 5d See Case 3.

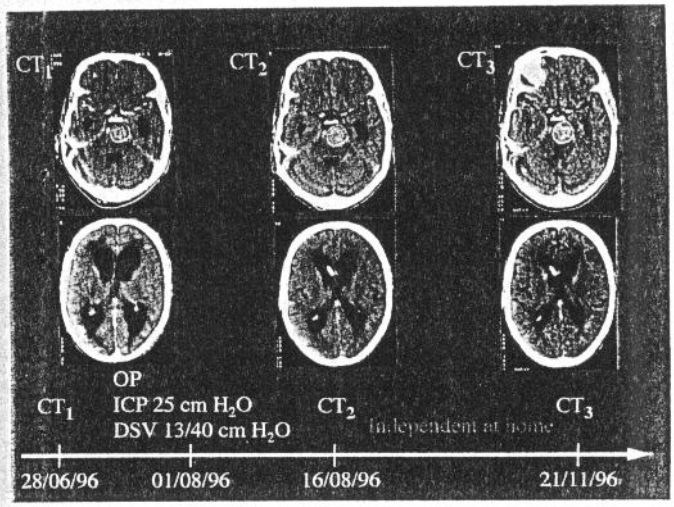

Fig. 6a See Cases 5 and 6.

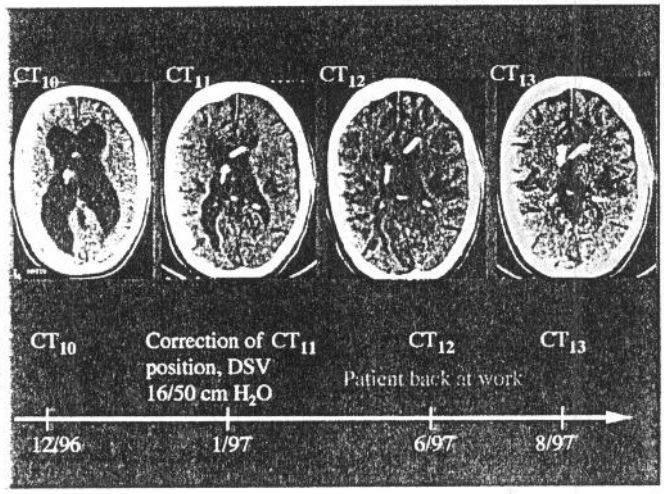

Fig. 5e See Case 3.

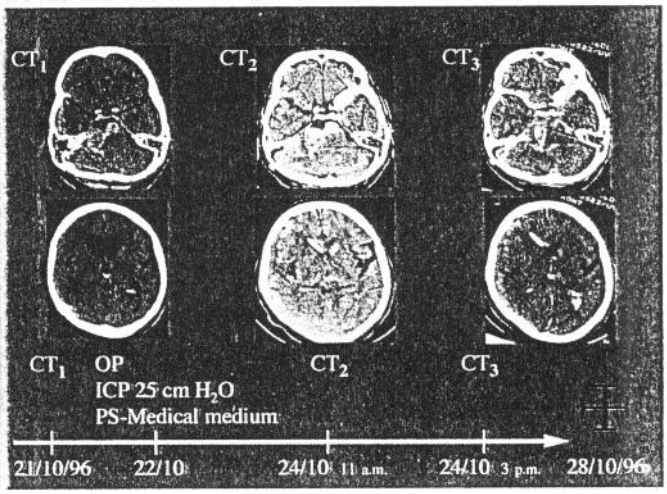

Fig. 6b See Cases 5 and 6.

the implantation of a medium-pressure valve. At that time the clinical state of drousiness had slightly improved, but only 5 hours later she became unconscious and a CT revealed a massive subarachnoid hemorrhage (SAH), in our opinion due to the too rapid decrease of the intracranial pressure (Fig. 6b).

Discussion

When we started our series with implantation of the DSV in the beginning of 1995, we were surprised by the high rate of only minimal or even no reduction of the ventricular size as in Case 1 (Fig. 3a and b), which was in contrast to other series (2, 5). We measured the intraventricular pressure via a *Rickham* reservoir in 7 cases without reduction of ventricular size, despite a considerable improvement in the clinical status. In all cases we evaluated physiological ICP values in the recumbent as well as in the upright position of the patient. Contrary to conventional differential-pressure valves with overdrainage in the upright position of the patient, the DSV keeps the intraventricular pressure in physiological ranges after shunting, which is often followed by an only a slight reduction of ventricular size. Our series give good evidence for our theory, that the maintainance of physiological IVP-ranges after shunting, including in the upright position, is the most important factor for success shunting.

Like other groups, we used several different methods to determine the clinical status before and after shunting (grading according to *Stein* and *Langfitt*, *Barthel* index, *Kiefer* index, *Black* series). All methods have special advantages and disadvantages in regard to the level of consciousness. Whereas the *Barthel* and *Kiefer* indices are more appropriate to people with normal-pressure hydrocephalus, cases suffering from severe subarachnoid hemorrhage or distinct brain injury are better graded on *Stein* and *Langfitt* or the *Black* series. In the light of the heterogeneous etiologies of our series, the excellent and good results in the majority of cases is difficult to interprete, because it is nearly impossible to compare the clinical course of a typical normal-pressure hydrocephalus patient with gait disturbance and incontinence with the improvement of an unconscious hydrocephalic patient after a severe SAH and clipping of an aneurysm. The clinical outcome of some cases in our series seems to be more dependent on the pre-shunt neurological status due to brain damage by a subarachnoid hemorrhage or a traumatic lesion rather than the feature of hydrocephalus. Thus it is difficult to compare the overall clinical outcome of our DSV patients to other series in the literature (2, 5).

We are aware that the illustrated patients are only case reports and of no statistical significance. But with them we want to stress again the danger of overdrainage in cases treated with differential-pressure valves. In our opinion the low rate of overdrainage-related complications in our series of 56 patients (only 1 transient hygroma and 1 patient with persisting hygromas [Case 3]) gives strong evidence of the capability of the DSV to avoid the sequelae of overdrainage without increasing the danger of clogging of the valve.