CASE REPORT

Use of CSF infusion studies to unblock occluded hydrocephalus ventricular shunt catheters: a preliminary report of two patients

Eva Nabbanja,¹ John Douglas Pickard,¹ Afroditi Despina Lalou,² Zofia Helena Czosnyka²

¹Clinical Neurosciences, Division of Neurosurgery, Cambridge University Hospital, Cambridge, UK

²University of Cambridge, Clinical Neurosciences, Cambridge, Cambridgeshire, UK

Correspondence to
Dr Afroditi Despina Lalou,
adl43@cam.ac.uk

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SUMMARY

Two patients with ventriculoperitoneal shunts presented with symptoms of raised intracranial pressure indicative of possible shunt malfunction. During investigation, to eliminate this possibility, cerebral spinal fluid infusion studies were performed, which indicated proximal occlusion of the shunts in both cases. Retrograde flush of the ventricular catheter was performed during temporary compression of the siphon-control device, a manoeuvre which blocks distal flow. After the use of this technique, both patients' symptoms improved and they have remained symptom-free for over 2 years. This case report validates the role that infusion studies can play in clearing a blocked ventricular catheter shunt.

BACKGROUND

The introduction of ventriculoperitoneal (VP) shunting as a treatment for hydrocephalus changed what was once a fatal disease into a manageable condition. However, there continue to be long-term problems with shunts.¹ The cumulative revision rate for shunts at 1 year is 24% for children and 14% for adults, increasing to 33% and 20% respectively by 5 years. The rates of revision are much higher for subsequent revisions (UK Shunt Registry).² The number of shunt revisions is associated with cognitive decline and risk of infection.^{1,3,4} Readmission, infection and reoperation impose a considerable economic burden.⁵ Various strategies are being developed to reduce the risk of shunt blockage and infection including innovative shunt components, antibiotic-impregnated catheters and infection control protocols. In this case report, we discuss the role of cerebral spinal fluid (CSF) infusion studies through the shunt reservoir to define the site of occlusion of a blocked shunt and the use of a retrograde flush through the reservoir to unblock it.

CASE PRESENTATION

Two patients were identified from the Cambridge Hydrocephalus Database. A 30-year-old woman (patient 1) presented to the emergency departments at a district general hospital with a 48-hour history of drowsiness, confusion and episodes of incontinence. Her shunt with a medium pressure non-adjustable valve had been inserted 15 years before for

aqueduct stenosis. Her Glasgow Coma Scale (GCS) was 14/15 (E:4, V:4, M:6). No nausea or vomiting was present and her inflammatory markers were low. The second patient was a 27-year-old man (patient 2) who was referred by a general practitioner with a 7-day history of headaches and nausea characteristic of raised intracranial pressure (ICP). His shunt with a Strata adjustable valve (Medtronic) had been inserted 2 years before for congenital hydrocephalus.

INVESTIGATIONS

Patient 1

The X-ray series showed that there was no kink or discontinuity with the shunt tip in the lower abdomen. A CT head scan without contrast showed a well-positioned right parietal ventricular catheter. Triventricular hydrocephalus with some temporal periventricular lucency was shown suggestive of a blocked VP shunt (figure 1, left).

Under aseptic conditions and with informed consent, an infusion study was performed. Two 25G butterfly needles were inserted into the prechamber of both shunt valves. One needle was used for recording pressure and the other needle for infusion of Ringer's lactate solution (figure 2A). The opening pressure was normal (8.5 mm Hg) but the pulse waveform was disproportionally small and barely detectable (figure 2B). Ringer's lactate solution was infused at 1.5 mL/min.^{6–8} After starting the infusion, the pulse amplitude further decreased (see AMP in figure 2A). The plateau ICP was reached almost immediately at 15.4 mm Hg. These results

Figure 1 CT scan evidence of marked reduction of the size of the ventricles before (left) and 7 months after infusion (right).

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Figure 2 (A) (Patient 1): Infusion study: intracranial pressure (ICP) (mm Hg); heart rate (HR) (beats/min); AMP, fundamental amplitude of ICP (mm Hg), RAP, compensatory reserve index (no unit index ranging from -1 to 1 ; values around 0 indicate good pressure-volume compensatory reserve). Opening pressure (8.5 mm Hg) with sluggish but detectable pulse waveform. Plateau ICP 15.4 mm Hg. After the start of infusion, the amplitude disappeared, which most often indicates partial blockage of the proximal catheter due to ingrowing choroid plexus (B) (Patient 2): Normal baseline (3.2 mm Hg), with plateau at 8.04 mm Hg. After the start of infusion, the amplitude of pressure pulsation increased and remained increased after end of infusion, demonstrating the unblocking of the proximal catheter. The retrograde flush was associated with an initial dip of the ICP due to artificial interference with the ICP signal.

indicated that the shunt was draining distally but the ventricular catheter was partially blocked, probably by choroid plexus ingrowing into a lumen of the catheter.

Interpretation of infusion parameters to detect shunt function

The interpretation of shunt testing *in vivo* derives from an extended and detailed knowledge of the different shunt properties from the Cambridge Shunt Laboratory⁹ and this is combined with over 25 years of experience of applying this knowledge to shunted patients and to clinical practice.¹⁰⁻¹² Using infusion studies, we are able to detect any problems with shunt function like underdrainage, proximal and distal blockage or overdrainage.^{9 11}

To detect shunt malfunction in these two patients, the CSF compensatory parameters investigated during an infusion study are: baseline and plateau ICPs (mm Hg), pulse amplitude of ICP (mm Hg), resistance to CSF outflow (mm Hg/(mL/min)).^{9 11 13} Compensatory parameters for each patient were calculated on the basis of individualised infusion test and analysed using computer-aided algorithm ICM+software (University of Cambridge, Cambridge Enterprise).

The results of a normal infusion study involve, as inferred by the above: normal baseline pressure with clearly detectable pulsatile amplitude of ICP and in line with the shunt type and setting, normal resistance depending on the type of shunt and normal plateau pressure, not exceeding the maximum pressure allowed by the shunt.^{9 10} If the latter does indeed exceed this

critical pressure, distal blockage is most likely present.^{9 10} With solid blockage of the ventricular catheter, aspiration of CSF is not possible. Baseline pressure is recordable; however, pulse waveform is not detected. This was not the case for the two patients. With a partial blockage of ventricular catheter (possible blockage by ingrowing choroid plexus), aspiration of CSF is possible. Pulse waveform is detectable. At the start of infusion, pressure increases but pulse amplitude disappears. This is presented in [figure 2A](#)—patient 1. Also, intermittent ventricular blockage can manifest with no pulsation at the start of baseline recording. At the start of the infusion, amplitude can be detectable.^{9 13–15} This is demonstrated in [figure 2B](#) of patient 2.

Patient 2

CT head showed no increase in the size of ventricles. It is not unusual for patients with VP shunt malfunction to lack radiographic evidence of ventricular dilatation on imaging.⁷ An infusion study performed revealed that the baseline pressure was low and non-pulsatile ([figure 2B](#)). After the start of infusion, ICP increased to 6 mm Hg and pulsations appeared. ICP stabilised at 10 mm Hg showing low resistance to distal flow. These results indicated intermittent blockage of the ventricular catheter.

TREATMENT

At the end of the infusion test, 2 mL of Ringer's lactate solution was injected into the shunt prechamber of both patients while distal flow was blocked by temporary compression of the occlusion chamber that is distal to the valve.

After the flush, both patients' ICP increased reaching plateau of 15 mm Hg for patient 1 and plateau of 8 mm Hg for patient 2 and the pulse waveform of undisturbed shape and magnitude reappeared.

OUTCOME AND FOLLOW-UP

Patient 1's GCS returned to normal and she was subsequently discharged home. At her 3-month follow-up appointment, she was symptom-free. A repeat CT head scan at 4 months ([figure 1](#), right) revealed resolution of hydrocephalus. Patient 2 was also reviewed in the clinic 3 months after treatment and was found to be free of the symptoms of raised ICP. In view of the clinical improvement and radiological picture for one of the patients, we received a confirmation of the indication from infusion studies that shunt blockage was alleviated.

DISCUSSION

Most proximal shunt obstructions occur within the inlet of the ventricular catheter⁸ and this is easily detected using infusion studies via a prechamber.^{8 9 13} Various patterns of shunt ventricular obstruction (slit ventricle, partial and solid blockages) have been described. In the absence of infection, ingrowth of choroid plexus into the fine holes in the ventricular catheter is a common cause of such proximal obstruction.^{9 10 14–16}

This case report illustrates how a CSF infusion study may be used to confirm whether a shunt blockage is present and whether the occlusion is partial or complete, proximal or distal. It also shows how a retrograde flush may be safely accomplished while compressing the distal occlusion mechanism built into the siphon-control component of the valve. We already use CSF infusion studies to avoid unnecessary readmission and revisions with reduced length of stay and cost savings.

The routine practice in our hospital is that the final decision for a shunt revision is made by the specialised clinical team responsible for the patient. The report from shunt infusion

tests is considered as high-quality, objective evidence,^{5–7} but imaging and clinical status of the patient are always considered jointly, knowing it has been reported that they are not always sufficient in revealing shunt malfunction.^{2 6–8} Similarly, the conclusion that the reported shunts were unblocked is based most importantly and due to safety reasons on the alleviation of the patients' symptoms in both cases shown and/or on the CT scan results on case 1; however, as illustrated in case 2, there was clear evidence of resolution of the blockage during infusion and after flushing. As for patient 1, infusion study could, but not as clearly, detect some resolution in the partial blockage but it was only confirmed after the end of infusion, when the patient improved and the CT scan revealed smaller ventricles.

Our experience with this technique is limited to Strata valves and fixed pressure valves with membrane antisiphon device (like the popular Delta valve). Concern is always taken that excessive rise in pressure within the prechamber might damage the valve mechanism; however, from the Shunt Laboratory, we know that a pressure up to 100 mm Hg is safe. Flushing should be always performed when the pressure in prechamber is monitored and reappearance of CSF pulse waveform is an indicator for successful manoeuvre. Complete or stubborn occlusion of a ventricular catheter may be reversed at the time of revision surgery using an intraluminal diathermy technique.^{11 12}

Learning points

- Risks and complications of shunt revisions pose a significant challenge; the use of infusion studies and retrograde flush to unblock the ventricular catheter can assist in the management of patients with hydrocephalus and avert readmission and surgical revision.
- Retrograde flush of the ventricular catheter may be achieved by injection of 2 mL of Ringer's lactate into the valve prechamber after temporary compression of distal drainage.
- A cerebral spinal fluid infusion study is a safe procedure with a low risk of infection as proven within our clinical department.

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Contributors EN contributed to planning the report, wrote the manuscript and collected the imaging and patients' data and information. ADL contributed to planning, assisted in writing and editing the manuscript and collected the patients' infusion data. JDP supervised the planning and organisation of the report, edited the manuscript and provided his expert feedback and editing in the end result. ZHC provided the idea for the report and gave her senior supervision and expertise to the interpretation of the patients' CSF infusion test results in the final report.

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