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ORIGINAL ARTICLE

# Shunt independence in paediatric hydrocephalus: our 16-year experience and review

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## Abstract

**Purpose** Shunt independence remains a matter of debate for neurosurgeons, and little information on this subject is available in the literature. The aims of the study were to analyse the incidence of shunt removal in a series of paediatric patients and to describe our experience with attempts at shunt removal.

**Methods** Thirty of 212 paediatric patients shunted between 2000 and 2016 at our institution were studied for shunt independence. Variables related to hydrocephalus aetiology, shunt complications, independence trial peculiarities and follow-up were recorded and a descriptive analysis of the data was performed.

**Results** Two patients (0.94%) refused to be included in a shunt independence trial and were analysed separately. In the other 28 patients, 29 shunt independence trials were performed, of which 19 (65.52%) were successful, giving a global rate of shunt independence of 8.96% (19/212) in our population. Secondary endoscopic third ventriculostomy was the most frequent type of independence trial and achieved the highest success rate (75%). Spontaneous independence was achieved in just 4/7 cases (57.14%). Planned removal of the shunt in overdrainage cases had a 50% success rate, with transient measures to control intracranial pressure frequently required.

**Conclusions** Shunt independence trials should be considered for selected patients in a closely monitored setting. Secondary endoscopic third ventriculostomy at the time of shunt malfunction has the highest success rate whereas planned removal of the shunt in overdrainage is an invasive procedure with more likelihood of failure. Shunt independence should not be presumed.

**Keywords** Shunt outcome · Secondary endoscopic third ventriculostomy · Shunt removal · Overdrainage

## Introduction

Only a few studies have been reported about shunt independence, even though this is a recurrent question for the patients and their families when the derivation system is implanted and for neurosurgeons when dealing with the expected shunt complications [1, 3, 4, 6–8, 17, 18]. Another matter of concern is the lack of consensus concerning the definition of shunt independency, the preferred way to achieve it and the real incidence of this event. In the absence of prospective studies and considering that only a few patients present spontaneous independence [7], shunt removal is most often elective, related to the possibilities of success of secondary endoscopic third ventriculostomy (ETV) [10] and usually performed in patients with frequent shunt dysfunctions and revision surgeries [4]. The achievement of shunt independence is currently from 3 to 9% of paediatric patients with hydrocephalus [8, 17].

The aims of this study were to analyse the incidence of shunt removal in our own series and to describe our experience in the different kinds of trials of shunt independence.

## Methods

### Patient selection

We undertook a retrospective review of 212 paediatric patients shunted for hydrocephalus at our institution between 2000 and 2016 and followed for at least one year after shunt surgery. Of the 212 patients, this review included just 30 (14.15%) who had been studied for shunt independence, were younger than 14 years of age at the time of first shunt insertion and had been

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followed for at least six months after shunt removal or ligature. Patients were excluded if they had been treated at another centre at any time or if they received their shunt due to arachnoid cyst, pseudotumour cerebri, or subdural collections.

### Baseline data and variables

Clinical data were obtained from our paediatric hydrocephalus database. Shunt independence was defined as the successful removal or ligature of all shunts, as reported by Vinchon et al. [17]. Shunt independence included patients with successful secondary endoscopic treatment (at the time of shunt malfunction), patients who became shunt-independent spontaneously (derivation system could be removed without any other treatment) and patients who underwent planned removal of their shunt in the context of a shunt independence protocol and secondary ETV or system ligation. We have used the term "shunt independence trial" to define any attempt at shunt independence in a patient in any of the scenarios previously described and "shunt independence protocol" to refer to those patients who had a planned removal of their shunt because of severe symptomatic overdrainage. Finally, as reported by Iannelli et al. [7], we also included cases in whom "cerebrospinal fluid (CSF) independence status" was presumed because of radiological demonstration of a "silent" CSF shunt occlusion or extrusion at a routine neuro-imaging control examination in the absence of any clinical manifestations, although independence could not be confirmed in our cases because of refusal by the family to give their consent; these cases were analysed separately.

Other variables collected were age in months at the time of first shunt insertion and at the date of attempted shunt independence, hydrocephalus aetiology (categorized as posthaemorrhagic, postinfectious, tumour, spinal dysraphism, primary, dysgenesis and other causes of secondary hydrocephalus), shunt revision surgeries, shunt infection and chronic symptomatic overdrainage.

Shunt infection was defined as previously reported by the Hydrocephalus Clinical Research Network [9] as follows: (1) identification of an infectious organism by culture or Gram stain of CSF, wound swab or pseudocyst fluid; (2) shunt erosion (defined as wound breakdown with visible shunt hardware); (3) abdominal pseudocyst (even in the absence of positive culture results); or (4) positive blood culture for a child with a ventriculoatrial shunt. A culture was performed for each patient who was thought to have a clinical shunt infection.

Symptomatic overdrainage was defined as previously reported by our group [8] as any episodic symptoms that improved after increasing valve outflow resistance, with or without the need for surgical revision of the system.

Finally, secondary ETV success in this group was determined using the criteria for success in paediatric neuroendoscopic procedures previously reported by our group [14]. The need for monitoring of intracranial pressure (ICP) and/or transient measures during the ETV adaptation period were also recorded.

### Statistical analysis

A descriptive analysis of the data was performed.

## Results

In 28 of the 30 patients, 29 shunt independence trials were performed with the aim of shunt ligation or removal. One of the patients underwent two shunt independence trials but both failed. The first trial was attempted because of a high suspicion of shunt independence in the context of slow valve refilling and a small but not collapsed ventricular size with peripheral placement of the catheter tip. The patient did not tolerate externalization and elevation of the shunt system nor was the ventricular size sufficient to be treated with ETV. The second trial was a secondary ETV after shunt failure due to infection. Two patients (0.94%) refused to be included in a shunt independence trial and were presumed to be independent following the definition of Iannelli et al., though they were followed regularly as if they had a functional shunt and analysed separately. Of the 29 shunt independence trials, 10 failed (34.48%) and 19 succeeded (65.52%), giving a global shunt independence rate of 8.96% (19/212) in our population. Complete removal of the shunt system was achieved in a minority of patients, who were mainly in the spontaneous independence group. A triple ligature distal or proximal to the valve was performed in some cases to ensure rapid access for CSF evacuation if it were necessary and in others to avoid complications related to ventricular catheter manipulation. Distal catheters and gravitational devices were removed in all cases. Figure 1 shows a schematic flow chart about the decision-making dynamics.

The median age at hydrocephalus diagnosis was 21.9 months (0–138), the median age at independence trial was 109.93 months (11–211) and the mean follow-up was 113.17 months (43–216) from diagnosis. The characteristics of the patients and the shunts at independence trial are shown in Table 1. The mean number of shunt revision surgeries and the rates of shunt infection or chronic symptomatic overdrainage were higher than expected, indicating that many of the patients were in a very complicated situation at the time of shunt independence trial. Table 2 summarizes the characteristics of the shunt independence trial. Tables 3 and 4 show the characteristics of the patients with successful or failed shunt independence trials, respectively.

Secondary ETV was the most frequent type of independence trial (12/29). Shunt failure was secondary to proximal

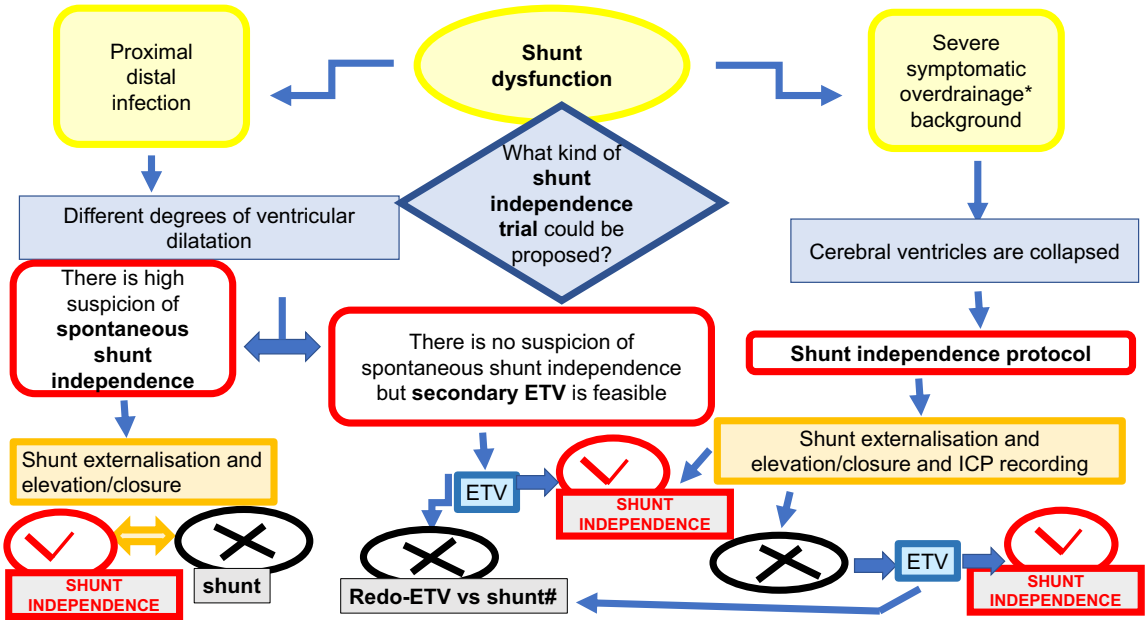


**Fig. 1** Schematic flow chart presenting the decision-making process. Asterisk indicates all patients in the "shunt independence protocol" group had a history of severe symptomatic overdrainage and small ventricles; although in some cases, the protocol was offered in the context of another complication. Number sign indicates when secondary ETV failed, Redo-ETV was the first option whenever possible and the second choice was a ventriculoperitoneal shunt. A lumboperitoneal shunt was considered only in patients with a background of resistant symptomatic overdrainage

occlusion (6/12), distal dysfunction (4/12) or infection (2/12). In all cases, externalization of the shunt or external ventricular drainage and shunt removal were performed and magnetic resonance imaging (MRI) was done as soon as possible to determine the ventricular anatomy. The MRI showed that 11/12 patients had obstructive hydrocephalus. ETV success following our classification criteria was obtained in 9/12 patients and the failures were all in cases of posthaemorrhagic aetiology. One of the successful cases is type IV (doubtful) and she is under close follow-up because she has refused ICP recording or surgery. Figure 2 shows a characteristic case in this group.

**Table 1** Patient and shunt characteristics at independence trial

| Characteristics | | Percent |
|---|---|---|
| Hydrocephalus aetiology | Posthaemorrhage | 43.3 |
| | Tumour | 26.7 |
| | Primary | 16.7 |
| | Spinal dysraphism | 6.7 |
| | Post-meningitis | 6.7 |
| Shunt revision surgery | Yes | 93.3 |
| | No | 6.7 |
| Mean number of shunt revision surgeries | 3.11 (1–9) | |
| Shunt infection | Yes | 20 |
| | No | 80 |
| Chronic overdrainage | Yes | 53.3 |
| | No | 46.7 |

A shunt independence protocol was attempted in patients with a background of symptomatic overdrainage, usually resistant to shunt upgrading and/or cranial expansion. In two patients, the ventricle was not large enough to perform ETV after externalization and elevation of the system because of clinical worsening and pathological ICP monitoring, so a new shunt system was implanted. In both patients, the shunt independence protocol was performed in the context of externalization of the distal catheter, one with appendectomy and the other with an abdominal infection. There were three shunt independence protocols without ETV. These cases showed radiological tumour regression after oncological treatment and experienced a decline in quality of life related to shunt overdrainage. All were demonstrated to be independent of the shunt, although one of the patients developed a "pseudotumour-like" syndrome needing serial lumbar punctures (approximately once a year) for CSF evacuation when there was an onset of a headache crisis. There was no papilloedema, visual acuity was preserved and tumour stability was confirmed. The last five patients were treated with ETV. Complete permanent success (type I) using both clinical and radiological criteria was obtained in two patients. One was previously treated with cranial expansion and posterior fossa decompression (Fig. 3). Another needed transient measures for ICP control after ETV and some months later the flow signal on MRI disappeared and a lumboperitoneal shunt was implanted. She developed resistant clinical overdrainage with reappearance of the flow artefact on sagittal T2FSE MRI and bidirectional flow signal on 2D-CPC MRI. The shunt was

**Table 2** Shunt independence trial characteristics

| Characteristics | | Percent/*N* |
|---|---|---|
| Shunt independence trial success | Yes | 65.52% (19/29) |
| | No | 34.48% (10/29) |
| Shunt independence trial type | Secondary ETV | 41.38% (12/29) |
| | Shunt independence protocol | 34.48% (10/29) |
| | Spontaneous independence | 24.14% (7/29) |
| Reason to offer the trial | Proximal dysfunction | 41.38% (12/29) |
| | Symptomatic overdrainage | 24.14% (7/29) |
| | Distal dysfunction | 17.24% (5/29) |
| | Shunt infection | 10.34% (3/29) |
| | Other | 6.9% (2/29) |
| ICP monitoring | Yes | 48.27% (14/29) |
| | No | 51.73% (15/29) |
| ETV | Yes | 58.62% (17/29) |
| | No | 41.38% (12/29) |
| Redo ETV | Yes | 40% (4/10) |
| | No | 60% (6/10) |
| Transient CSF evacuation measures after ETV | Yes | 33.33(7/21) |
| | No | 66.67(14/21) |
| ETV success classification at present Ros et al [14] | Type I (complete permanent success) | 58.8% (10/17) |
| | Type IV (doubtful) | 5.9% (1/17) |
| | Type V (failure) | 35.3% (6/17) |

ligated and clinical improvement was later verified. She is in close follow-up. One patient in this group experienced type IV success (doubtful) for six years because there was clinical stability (quite better than with overdrainage) and the same ventricular size with no flow artefact after a second ETV. He and his family refused a new ICP recording or shunt surgery, so he was followed closely at the outpatient clinic. Recently, we have observed a slight increase in ventricular size on MRI control and he is due to be shunted shortly. Finally, there were two shunt independence protocols with ETV failure. One of them soon after surgery and a new ventriculoperitoneal shunt was inserted, and the other presented papilloedema without headache or clinical worsening at a routine control five months after ETV. This patient was treated with a lumboperitoneal shunt.

Spontaneous independence was assumed in those cases where it was clearly suspected. Some of these showed progressive caudal displacement of the system until extrusion in serial image studies, with no significant changes in ventricular size (Fig. 4). All the shunts were externalized and elevated or closed for 24–72 h, and in 4/7 cases, independence was demonstrated and the shunts were removed; three of these were posthaemorrhagic hydrocephalus and the other was tumour hydrocephalus. The other three cases were demonstrated to be shunt-dependent, with clinical and/or ICP worsening after externalization and elevation of the system, and their ventricular shunts were replaced. The hydrocephalus aetiologies in these three cases were posthaemorrhagic in two and congenital non-obstructive hydrocephalus in one. All the patients with spontaneous independence were followed in external clinics for at least one year. They represent 1.89% of all the patients in the whole series (4/212).

## Discussion

Shunt independence has been a target for neurosurgeons since the development of shunt surgery. Historically, it has been closely related with attempts to manage shunt complications, mainly for overdrainage prevention or treatment, and several techniques have been described to achieve independence (intermittent cranial compression with ICP monitoring, "on-off" type of shunts, subtemporal craniectomy) [6]. In the 1980s and early 1990s, this topic was addressed at several meetings (Shunts and Problems in Shunts Symposium, Marseille, June 1980; Consensus Conference: Hydrocephalus '92, Assisi, Italy). Definitions were developed for shunt independence and compensated or arrested hydrocephalus, and the first attempts to determine shunt dependency were performed (ventricular infusion test, telemetric devices for ICP measurement…), with controversial results. The consensus of the speakers at that time was that "there was no single test that reliably confirmed that a shunt was not functioning and they all agreed that shunt removal was always associated with an

**Table 3** Characteristics of patients with successful shunt independence trials

| Patient | Reason for shunt independence trial | Surgical procedure | Success in which category | Subsequent surgeries |
|---|---|---|---|---|
| 1 | Distal dysfunction | ETV | Secondary ETV | Redo-ETV |
| 2 | Distal dysfunction | ETV | Secondary ETV | Redo-ETV |
| 3 | Distal dysfunction | ETV | Secondary ETV | Redo-ETV |
| 4 | Distal dysfunction | ETV | Secondary ETV | No |
| 5 | Proximal dysfunction | ETV | Secondary ETV | No |
| 6 | Proximal dysfunction | ETV and aqueductoplasty | Secondary ETV | No |
| 7 | Proximal dysfunction | ETV | Secondary ETV | No |
| 8 | Shunt infection | ETV | Secondary ETV | No |
| 9 | Proximal dysfunction | ETV | Secondary ETV | No |
| 10 | Proximal dysfunction | Shunt externalization and elevation/closure | Spontaneous independence | No |
| 11 | Proximal dysfunction | Shunt externalization and elevation/closure | Spontaneous independence | No |
| 12 | Proximal dysfunction | Shunt externalization and elevation/closure | Spontaneous independence | No |
| 13 | Other (thalamic astrocytoma reoperation) | Shunt externalization and elevation/closure | Spontaneous independence | No |
| 14 | Symptomatic overdrainage | Shunt externalization and elevation/closure | Shunt independence protocol | No |
| 15 | Symptomatic overdrainage | Shunt externalization and elevation/closure | Shunt independence protocol | No |
| 16 | Symptomatic overdrainage | ETV | Shunt independence protocol | No |
| 17 | Other (non-specific neurological symptoms) | Shunt externalization and elevation/closure | Shunt independence protocol | No |
| 18 | Symptomatic overdrainage | ETV | Shunt independence protocol | Redo-ETV (ETV failure recently diagnosed, pending new shunt[a]) |
| 19 | Symptomatic overdrainage | ETV | Shunt independence protocol | Lumboperitoneal shunt as transient measure |

[a] This patient was included in the successful shunt independence group because the failure of his ETV occurred outside the time of the study and he was shunt-independent during 6 years

**Table 4** Characteristics of patients with failed shunt independence trials

| Patient | Reason for shunt independence trial | Surgical procedure | Failure in which category | Subsequent surgeries |
|---|---|---|---|---|
| 1 | Symptomatic overdrainage | ETV | Shunt independence protocol | Lumboperitoneal shunt |
| 2 | Symptomatic overdrainage | ETV | Shunt independence protocol | Ventriculoperitoneal shunt |
| 3 | Distal dysfunction without ventricular dilatation | Shunt externalization and elevation/closure | Shunt independence protocol | Ventriculoperitoneal shunt |
| 4 | Shunt infection without ventricular dilatation | Shunt externalization and elevation/closure | Shunt independence protocol | Ventriculoperitoneal shunt |
| 5 | Proximal dysfunction | ETV | Secondary ETV | Ventriculoperitoneal shunt |
| 6 | Proximal dysfunction | ETV | Secondary ETV | Ventriculoperitoneal shunt |
| 7 | Proximal dysfunction | Shunt externalization and elevation/closure | Spontaneous independence | Ventriculoperitoneal shunt |
| 8 | Proximal dysfunction | Shunt externalization and elevation/closure | Spontaneous independence | Ventriculoperitoneal shunt |
| 9[a] | Proximal dysfunction<br>Shunt infection | Shunt externalization and elevation/closure<br>ETV | Spontaneous independence<br>Secondary ETV | Ventriculoperitoneal shunt<br>Ventriculoperitoneal shunt |

[a] This patient underwent two shunt independence trials but both failed (see text)

element of hazard and that it should not be carried out except in the most exceptional circumstances."

In 1998, Baskin et al. [1] reported a study of a shunt removal protocol for symptomatic overdrainage refractory to increased shunt resistance and medical therapy that should be considered a frame of reference in this issue. They used an algorithm to treat 22 patients with symptomatic overdrainage independently of the hydrocephalus aetiology and included secondary ETV as an alternative CSF diversion. They achieved 22.7% spontaneous independences (5/22) and 62.5% with secondary ETV (10/16) after around two years of follow-up. In our study, spontaneous independence was obtained in 30% of patients (3/10) and successful secondary ETV in 40% (2/5), with a mean of 38.2 months of follow-up.

Analysing our failures, we believe that our first protocol was considered to be a failure too soon. Nowadays, we would have tried to use some "ETV rescue measures" [2, 5, 12] before inserting a new shunt. Two other patients were deferred and had asymptomatic failures: one detected because of papilloedema at a routine clinical control some months after

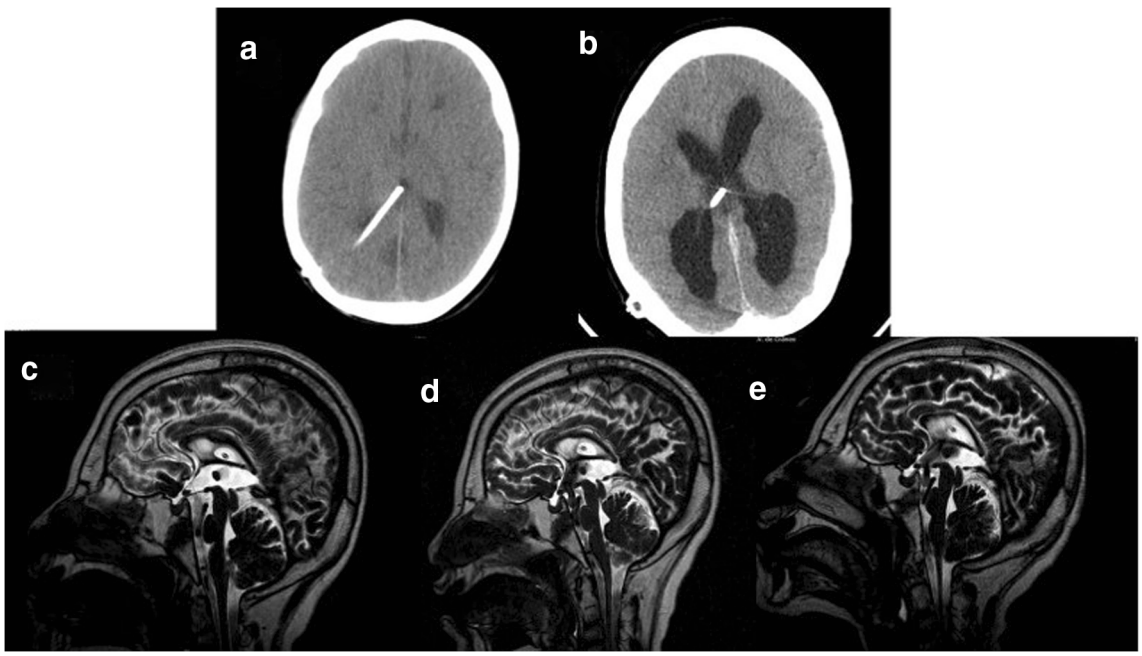


**Fig. 2** Prematurely born patient with primary hydrocephalus shunted in the neonatal period. Several distal failures with peritoneal absorption problems and aqueductal stenosis. **a** Functioning shunt. **b** Distal shunt dysfunction with ventricular widening. **c** Early failure of ETV without flow artefact on postoperative MRI. **d** Successful Re-do ETV. **e** Control MRI 43 months after shunt independence

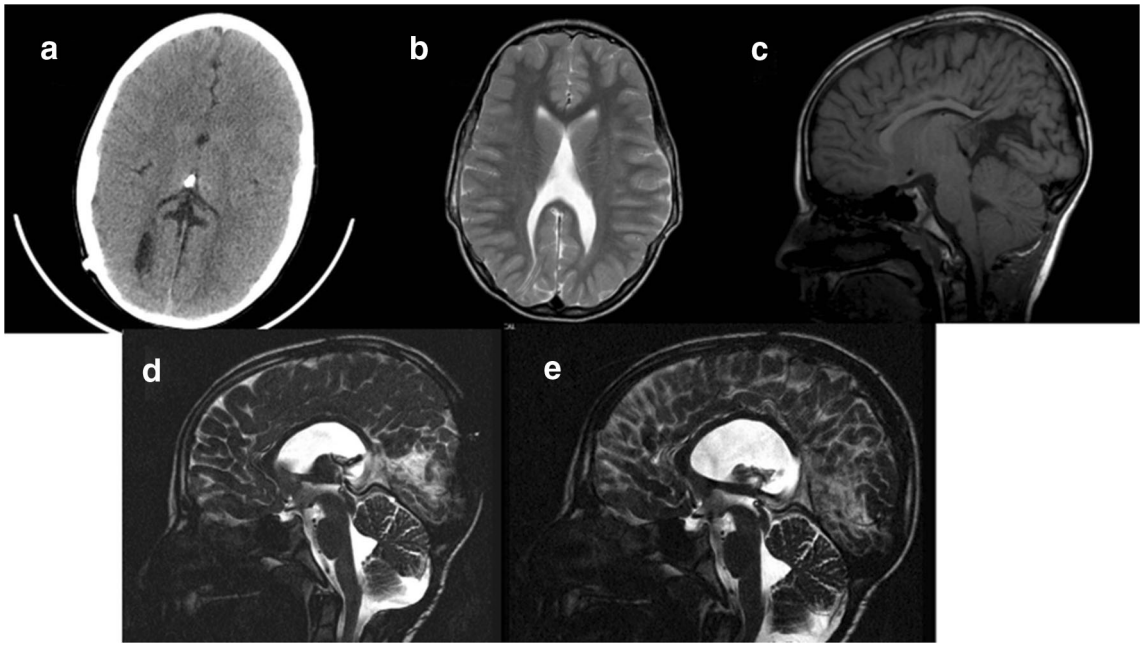


**Fig. 3** Prematurely born patient with posthaemorrhagic hydrocephalus shunted in the neonatal period. **a** Symptomatic overdrainage with several emergent hospital admissions, even to the intensive care unit. High-resistance shunt system. **b** Transitory improvement of ventricular size and overdrainage symptoms after supratentorial cranial expansion. **c** Persistent symptomatic overdrainage after supratentorial expansion and posterior fossa decompression. **d** MRI after shunt independence protocol with shunt externalization, ICP monitoring and ETV. **e** Control MRI six months after shunt independence

the procedure and the other 72 months after ETV on a control MRI. This once again shows how important it is to follow these patients closely over a long time. Clinical improvement after shunt independency compared with overdrainage in our patients impacted greatly on their quality of life, so the parents usually preferred not to insert a shunt again until the appearance of criteria for complete failure.

In two of our patients, not enough ventricular size to perform ETV was achieved after externalization of the shunt system because of clinical or ICP worsening. For this kind of patient, Chernov et al. [3] propose a different system to increase ventricular size with endoscopic change of ventricular catheter, programmable shunt implantation and progressive upgrading of the shunt opening pressure. ETV was performed a mean of 16.3 months after the first procedure. Our experience was that if children improved clinically after shunt revision with a higher resistance system without changing the proximal catheter (we do not usually change a ventricular catheter because of the risk of haemorrhage in this manoeuvre), the parents preferred to wait and consider shunt independence in the context of a future shunt failure.

It was also in 1998 when Cinnalli et al. reported their results after treating 30 patients with obstructive hydrocephalus and shunt malfunction or infection with ETV. They obtained a shunt independence rate of 76.7% and noted three technical failures at the time of surgery and four within a median of 10 days. They had no delayed failures over a median follow-up of 8.7 years. Our independence rate was 75% (9/12) over a mean follow-up of 69.44 months, although three of these patients needed a second ETV. One of these three was an early failure secondary to technical problems during surgery (Fig. 2) and the other 2 occurred 28 and 34 months post-ETV (both myelomeningoceles with loss of radiological criteria without clinical worsening). Failures were shunted within six months after ETV; one patient was shunted soon after surgery due to worsening of clinical and ICP monitoring, and the other two were shunted because of subacute neurological symptoms and loss of radiological criteria.

In our department, secondary ETV is usually recommended for patients with obstructive hydrocephalus (either primary or acquired [15]) with repeated shunt malfunctions or a background of complex management of the derivation, and it is performed in scheduled surgery, usually with prior emergent externalization of the shunt or EVD surgery. The reasons for this relate to the availability of MRI and possible technical difficulties, which mean this procedure is usually scheduled to be done by more experienced neuroendoscopic surgeons. Anyway, we agree with the general recommendation to offer this possibility to patients with hydrocephalus and a favourable anatomy at the time of shunt failure [4, 18].

Another matter of concern is that some patients show a transient period of clinical signs or symptoms of raised ICP after secondary ETV or different patterns of transient intracranial hypertension, though these do not represent failure of the procedure [2, 12, 13]. This adaptation period could be related to absorption problems and can possibly be predicted

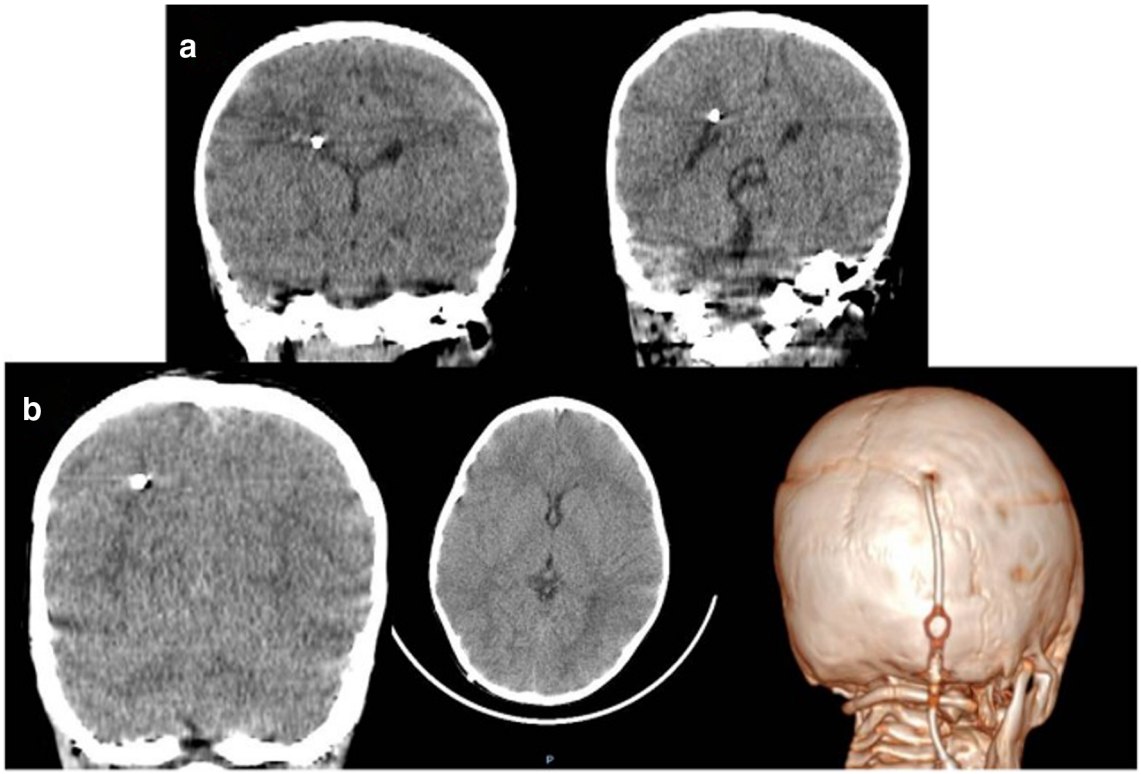


**Fig. 4** Patient with posthaemorrhagic hydrocephalus shunted in the neonatal period. **a** CT scan with ventricular catheter located marginal in the right frontal horn with small ventricular size. **b** Control CT scan after clinical observation of asymptomatic shunt reservoir collapse showing caudal displacement of the shunt system and extraventricular location of ventricular catheter without ventricular widening

depending on age at diagnosis, hydrocephalus aetiology (mainly in children who have congenital or perinatally acquired hydrocephalus), intraoperative findings and events and postoperative clinical course plus ICP recording analysis. This period has been explained by the chronic compression exerted on capacitance vessels and basal cisterns by continuous intracranial hypertension and the time each patient needs to restore their physiological absorption pathways [5, 12]. In selected cases, an external ventricular or lumbar drain or postoperative lumbar punctures have been used to release the pressure during this period [2, 5, 12]. These strategies could facilitate flow through the stoma, release intraventricular CSF, decrease ICP and help the restoration of the CSF pathways. Ozisik suggested that ICP monitoring after ETV should be routinary, at least in complicated cases [12], although other authors concluded that given the lack of evidence, ICP monitoring was not required, but they still recommended its consideration in the setting of secondary ETV [18]. In our opinion, ICP recording in selected patients for even longer than was used in the previous reports and qualitative analysis of ICP waves may provide very valuable information about the adaptation period and the compliance and absorption adjustments. Nevertheless, how long one should monitor the adaptation period after ETV treatment of hydrocephalus is still a matter of controversy, as also are the best method to manage this period and at what point the ventriculostomy should be declared an early failure [2, 5, 12, 13, 18]. In accordance with the experience of Bellotti, Cinalli, and Ozisik [2, 5, 12], we prefer to use CSF-limited drainage with EVD opening or lumbar punctures initially and later on continuous spinal drain in more complex cases to control transient increases of ICP. Nevertheless, ETV rescue after lumboperitoneal shunt in one of our patients was an unexpected event.

Another issue of concern is when MRI is unable to demonstrate flow through the stoma despite clinical and ICP recording improvement. One explanation for this could be that the major CSF pathway has still not fully developed and the minor pathway has a significant role, thus failing to arrest the hydrocephalus [11, 16]. In these cases, it would be necessary to use objective evaluations to assess the real advantages of ETV versus extracranial shunts.

In 2005, Iannelli et al. reported a rate of 3.2% (27/850) of patients with non-tumour hydrocephalus with "obvious shunt independence" demonstrated at the time of shunt lengthening or confirmed after high clinical and radiological suspicion, with a mean postoperative observation period of 12 years [7]. In our series, this kind of independence study was only offered to patients who were considered to be highly likely to become independent, though it was only successful in 57.14% (4/7) of cases. As previously reported, progressive "maturation" of the anatomo-functional mechanisms related to CSF absorption could be the most probable event [11]. In any case,

each case of suspected shunt independence should be confirmed before releasing the patient from outpatient clinics, and if independence is not confirmed, the patient should be followed as shunt-dependent.

Finally, in 2012, Vinchon et al. in their review about paediatric hydrocephalus outcomes presented the first unified definition of shunt independence and set the bases of current management of this issue: Shunt independence does not mean a cure for hydrocephalus in most cases; some period after shunt removal is necessary to assert that the patient is truly shunt-independent and a long follow-up is recommended [17].

### Limitations

The major limitations of this study concern its single-centre nature, the retrospective assessment of variables and the low total number of patients in the sample.

## Conclusions

Shunt independence with secondary ETV in obstructive hydrocephalus at the time of shunt malfunction has elevated rates of success and should be offered in a suitable context. Planned removal of the shunt in symptomatic shunt overdrainage is an invasive procedure and should only be considered in strictly selected patients, with close monitoring and a long follow-up. Our "true independence" rate is low, probably because it was only considered in cases that were likely to be successful. Caution should be exercised before considering a patient shunt-independent without confirmation. Some of our patients who were considered to be independent were later demonstrated to be shunt-dependent.

### Compliance with ethical standards

**Conflict of interest** On behalf of all authors, the corresponding author states that there is no conflict of interest.

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