Radiographic Shuntogram for Diagnosis of CSF Ventricular Shunts Malfunction

Mohammad Taghyan MD, Roshdy A.Elkhayat MD, Mohammad A.Meckawy, Mostafa M.Mostafa**, Hassan M.Hassan Msc.*
Neurosurgery,*Radiotherapy&Nuclear Medicine and **Radiology Departments, Assiut University Hospital, Assiut, Egypt

ABSTRACT

Background: *Ventriculoperitoneal or ventriculoatrial shunt malfunction is a common problem and sometimes difficult to diagnose and manage. Clinical presentation in patients with shunt malfunction is typically nonspecific, and brain imaging often fails to show a change in ventricular size. The radiographic shuntogram is a simple method to evaluate the function and patency of a ventriculoperitoneal or ventriculoatrial shunt.* ***Patients and technique:*** *The procedure involves placing nonionic contrast material into the valve of a shunt system and following the flow for appropriate clearing of contrast agent from the shunt tubing by serial filming over a 15-minute period. The method can be used to establish valve malfunction, ventricular or distal catheter obstruction, and peritoneal encystment. Thirty four studies were obtained in 31 patients in whom shunt malfunction was suspected.* ***Results:*** *patients were verified into 18 (58.1%) males and 13 (41.9%) females, the average age was14 years. Radiographic shuntogram results were 25 (73.5%) true positive studies, 6 (17.6%) true negative studies, 3 (8.8%) false negative studies and no false positive results. The sites of true positive cases verified into 15 (60%) distal block, 9(36%) proximal block, 2 (8%) proximal and distal blocks (tube disconnection) and 2 (8%) valve malfunction.* ***Conclusion:*** *our opinion favour the use of radiographic shuntogram in the diagnosis of obstructed CSF ventricular shunts as it is simple procedure, minimally invasive and is rapid as well as easy to perform. Its advantage over other methods lies in not only diagnose shunt malfunction but also localize and qualify the malfunction thus it can be used to establish valve malfunction, ventricular or distal catheter obstruction, and peritoneal encystment aiding the neurosurgeon in targeting the part of the shunt requiring revision.*

Key words: *Ventriculoperitoneal or ventriculoatrial shunt malfunction, radiographic shuntogram.*

INTRODUCTION

Ventriculoperitoneal or ventriculoatrial shunt malfunction is a common problem and sometimes difficult to diagnose and manage. Clinical presentation in patients with shunt malfunction is typically nonspecific, and brain imaging often fails to show a change in ventricular size. The radiographic shuntogram is a simple minimally invasive examination that can easily be used to evaluate the flow characteristics of a ventriculoperitoneal or ventriculoatrial shunt. Problems such as ventricular catheter obstruction, valve pressure choice, and distal catheter obstruction can often be separated, aiding the neurosurgeon in targeting the part of the shunt requiring revision. Demonstration of normal shunt function directs the neurosurgeon to seek other causes for the patient's clinical changes.

Technique and patients

Radiographic shuntogram was done for thirty-one patients in whom shunt malfunction was suspected and were admitted to Neurosurgery Department, Assiut University Hospital over a two-year period (December 2004 to December 2006). Their ages ranged from 3 months to 45 years with a mean age of 14 years. They verified into 18 (58.1%) males and 13 (41.9%) females. Systemic infection was excluded to be the cause of the patient's neurological status in all patients.

The radiographic shuntogram involves injection of a small quantity of nonionic contrast material into the valve of a ventricular shunt system. Serial filming is performed over a 15-minute period to document forward flow of contrast material and CSF. Pumping the shunt prior to obtaining the final radiographs ensures complete system function.

With the patient supine, the head is turned for optimal display of the shunt system and scout radiographs of the cranial, chest, and abdominal components of the shunt are obtained. The shunt valve is located and scalp hair is generously removed from the valve region. The skin overlying the valve is thoroughly cleansed with Betadine and a sterile drape is placed over the field. By palpation and with fluoroscopic guidance, the valve is entered by using a 25-gauge butterfly needle which is connected to adequate extension tubing. Free backflow of CSF confirms proper placement within the valve. A 5-mL syringe is connected to the butterfly system and a minimal amount (1–2 mL) of CSF is gently withdrawn. This provides fluid for analysis and confirms free flow in the ventricular component of the system. Resistance to CSF withdrawal suggests ventricular component obstruction or valve malfunction, and continued withdrawal should not be forced. Only a small amount of CSF should be removed, since excessive withdrawal of CSF would diminish the pressure gradient and can reduce CSF flow through the shunt system. Five mL of Iopamidol (Ipemero) is then injected into the shunt valve and serial filming of the cranial, chest, and abdominal components of the shunt system are obtained at 3, 6, 9, and 12minutes. At 15 minutes, the shunt valve is pumped 30 times to effect complete clearing of the shunt system and final films of all regions are obtained.

The shuntogram was considered functioning and normal if CSF could be withdrawn from the reservoir and if evidence of spontaneous forward flow of contrast was demonstrated within the first 12 minutes. Free peritoneal spillage should be identified in patients with functioning ventriculoperitoneal shunts. The abnormal shuntogram can reveal several different shunt problems: 1) ventricular catheter obstruction or valve malfunction is suspected if CSF cannot be freely withdrawn from the reservoir; 2) valve malfunction is present when contrast material freely refluxes from the valve reservoir into the ventricular system; 3) valve malfunction with inappropriate valve resistance or incomplete obstruction of the shunt system is suggested when contrast material does not empty from the shunt spontaneously but the system can be cleared after pumping the reservoir; 4) peritoneal obstruction of the distal catheter is suspected if free spillage of contrast into the peritoneal cavity is not present or if inappropriate peritoneal or visceral accumulation of contrast material is identified; and 5) complete distal obstruction is present if contrast material cannot be cleared from the tube after pumping the valve.

RESULTS

Patient's demographics

Thirty four studies were obtained in thirty one patients, their ages ranged from 3 months to 54 years with the mean age of 14 years. They verified into 18 (58.1%) males and 13 (41.9%) females.

The results of the shuntograms are summarized in the following tables (1, 2, 3 in order)

Table (1): Shunt type, imaging results, and surgical findings in patients undergoing a shuntogram

Pt. No.	shunt type	Valve pressure	CSF withdrawal	Spontaneous Peritoneal spill	Spill After pumping	Shuntogram interpretation	Finding at surgical revision
1.	DV-VP	MP	Yes	No (localized Collection)	No	Abnormal	Distal occlusion
	DV-VP	MP	No	Yes	Yes	Abnormal	Proximal occlusion
2.	DV-VP	MP	Yes	No	No	Abnormal	Distal occlusion
3.	DV-VP	MP	Yes	No (localized Collection)	No	Abnormal	Distal occlusion
4.	DV-VP	MP	Yes	Yes	Yes	Normal	Proximal occlusion
5.	DV-VP	MP	Yes	Yes	Yes	Normal	No surgery done
6.	DV-VP	MP	No	Yes	Yes	Abnormal	Proximal occlusion
	DV-VP	MP	Yes	Yes	Yes	Normal	Distal occlusion
7.	DV-VP	MP	Yes	No	No	Abnormal	Distal occlusion
8.	DV-VP	MP	Yes	Yes	Yes	Normal	No surgery done
9.	DV-VP	MP	Yes	No	No	Abnormal	Distal occlusion
10.	DV-VP	MP	Yes	Yes	Yes	Normal	No surgery done
11.	DV-VP	MP	Yes	Yes	Yes	Normal	No surgery done
12.	DV-VP	MP	Yes	No	No	Abnormal	Distal obstruction
13.	DV-VP	MP	No	Yes	Yes	Abnormal	Proximal occlusion
	DV-VP	MP	Yes	No	No	Abnormal	Distal occlusion
14.	DV-VP	MP	Yes	Yes	Yes	Normal	No surgery done
15.	DV-VP	MP	No	Yes	Yes	Abnormal	Proximal occlusion
16.	DV-VP	MP	Yes	No	No	Abnormal	Distal occlusion
17.	DV-VP	MP	No	No	No	Abnormal	Disconnection
18.	DV-VP	MP	Yes	Yes	Yes	Normal	Proximal occlusion
19.	DV-VP	MP	No	Yes	Yes	Abnormal	Proximal occlusion
20.	DV-VA	MP	Yes	Yes	Yes	Normal	No surgery done
21.	DV-VP	MP	Yes	No	No	Abnormal	Distal occlusion
22.	HV-VP	MP	No	Yes	Yes	Abnormal	Proximal occlusion
23.	DV-VP	MP	Yes	No	Yes	Abnormal	Valve malfunction
24.	DV-VP	MP	No	Yes	Yes	Abnormal	Proximal occlusion
25.	DV-VP	MP	Yes	No(localized Collection in U.B)	No	Abnormal	Distal occlusion
26.	HV-VP	MP	No	No	No	Abnormal	Disconnection
27.	DV-VP	MP	Yes	No	No	Abnormal	Distal occlusion
28.	DV-VP	Mp	Yes	No	No	Abnormal	Distal occlusion
29.	DV-VP	MP	Yes	No	No	Abnormal	Distal occlusion
30.	DV-VP	MP	Yes	No	No	Abnormal	Distal occlusion
31.	DV-VP	MP	Yes	No	Yes	Abnormal	Valve malfunction

DV= Delta valve, HV= Holter valve, VP= Ventriculoperitonael, VA= Ventriculoatrial, MP= Medium pressure

Table (2): Summary of radiographic shuntogram results

Radiographic shuntogram results	*No. of studies (shuntograms)*	*% of cases*
False positive	0	0
False negative	3	8.8
True positive	25	73.5
True negative	6	17.6

Table (3): Summary of shunt problems (true positive + false negative)

Proximal block	9
Distal block	15
Valve malfunction	2
Disconnection	2

In six studies (17.6%), shuntogram was normal (patients No.5, 8, 10, 11, 14, 20) and these shunts were not surgically revised as the patients symptoms recovered spontaneously (specificity=100%) (**Fig.1**). However, in three studies (8.8%) the shuntogram was normal and in the view of persistence of the patient's symptoms these shunts were revised and two proximal and one distal occlusions were documented (patients No.4, 6, 18) and thus the negative predictive value= 66.7%. The shuntogram was abnormal with slow or absent flow into the peritoneal cavity in 25 (73.5%) studies (sensitivity=89.3%, accuracy=91.2% and positive predictive value=100%). In all 25 instances, the shunt system was revised with excellent results. The most common shunt problem encountered was distal block (15 studies). The shuntogram demonstrated absence of spontaneous flow with absent post pump clearing at 15 minutes but free CSF withdrawal in11 instances (distal blockage) (**Fig.2**), two studies proved surgically to be disconnection and the shuntogram demonstrated absence of spontaneous flow with absent post pump clearing at 15 minutes and no free CSF withdrawal (**Fig 3**). Distal obstruction caused by peritoneal adhesions with an abnormal distal CSF collection was observed in three studies (**Fig.4**), one of them the tip of the distal catheter was found in the urinary bladder. Proximal block was encountered in 7 studies with the shuntogram demonstrating absence of free CSF withdrawal (**Fig.5**). The shuntogram demonstrated absence of spontaneous flow but free CSF withdrawal and shunt clearing after pumping at 15 minutes denoting valve malfunction in two instances (**Fig.6**).

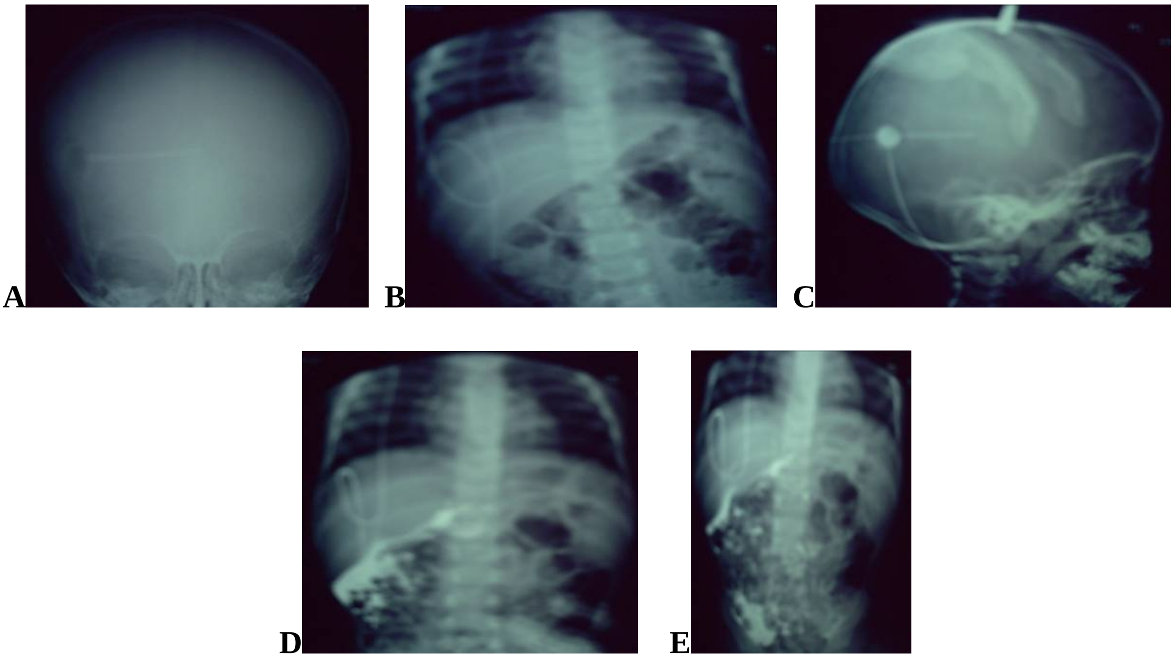

Fig. (1) Case 10: male patient 2 years old, radiographic shuntogram was normal as evidenced by easy aspiration of CSF and free peritoneal spilling of contrast

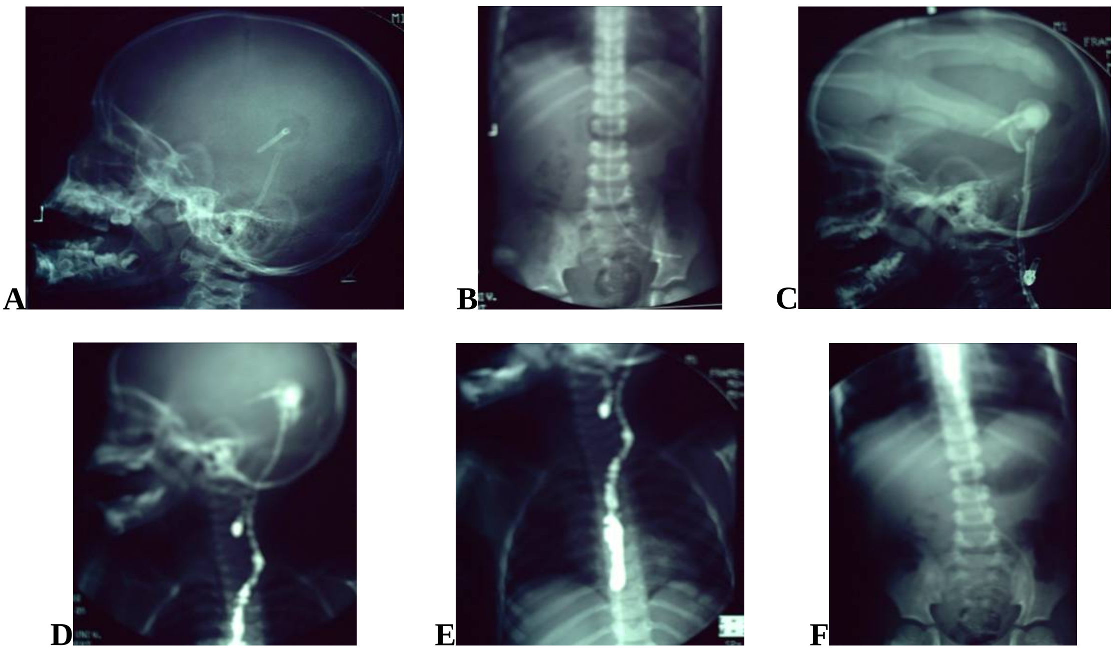

Fig. (2): Case 16: female patient, 5ys old, radiographic shuntogram revealed no free peritoneal spilling of contrast material even after post pumping test denoting distal obstruction.

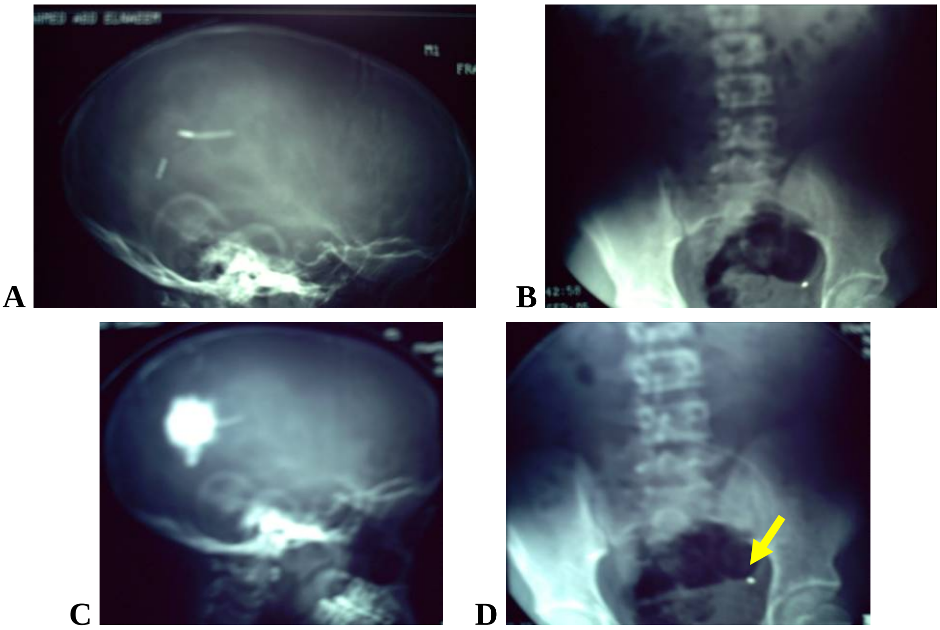

Fig. (3): Case17: male patient, 17ys old, radiographic shuntogram revealed disconnected distal tube from reservoir with no free peritoneal spilling

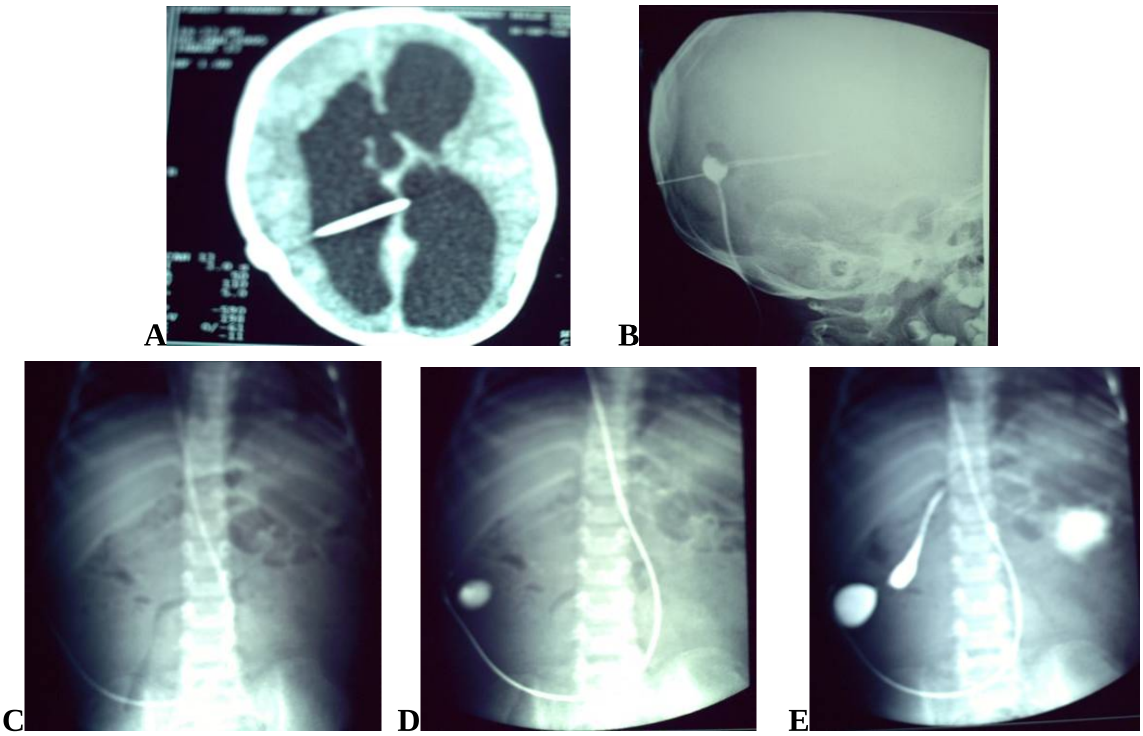

Fig. (4) Case: 3 male patient 6 years old, note that CT brain showed dilated ventricles, radiographic shuntogram revealed that there was localized peritoneal collection of contrast material denoting distal obstruction due to peritoneal adhesion and CSF was easily aspirated from reservoir

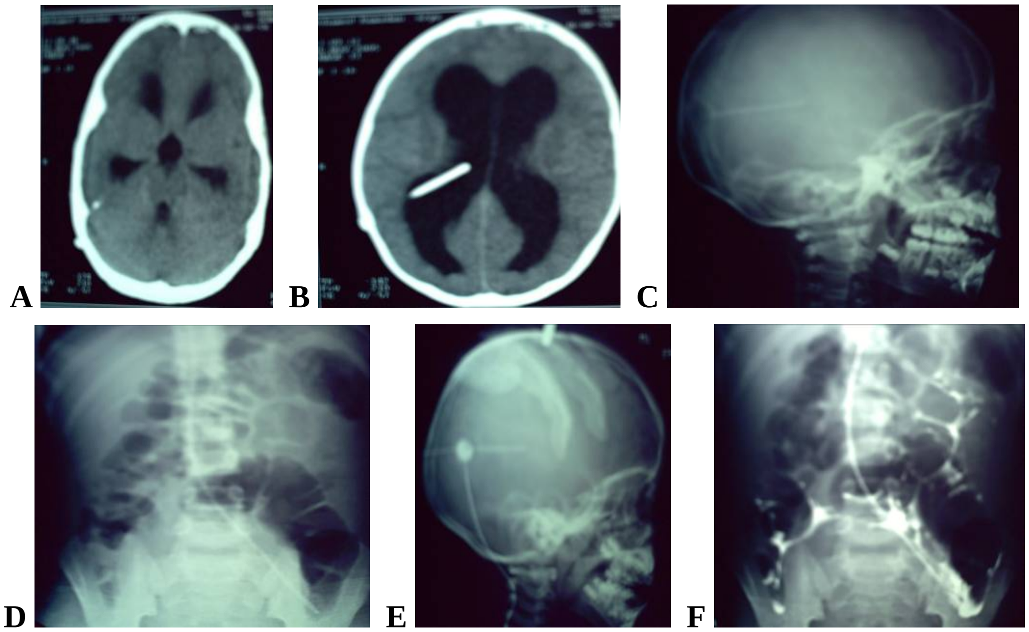

Fig. (5): Case 19: male patient 7 yrs. old, CT brain revealed dilated ventricles. No CSF aspiration from reservoir, and radiographic shuntogram revealed free peritoneal spill of contrast material (proximal obstruction).

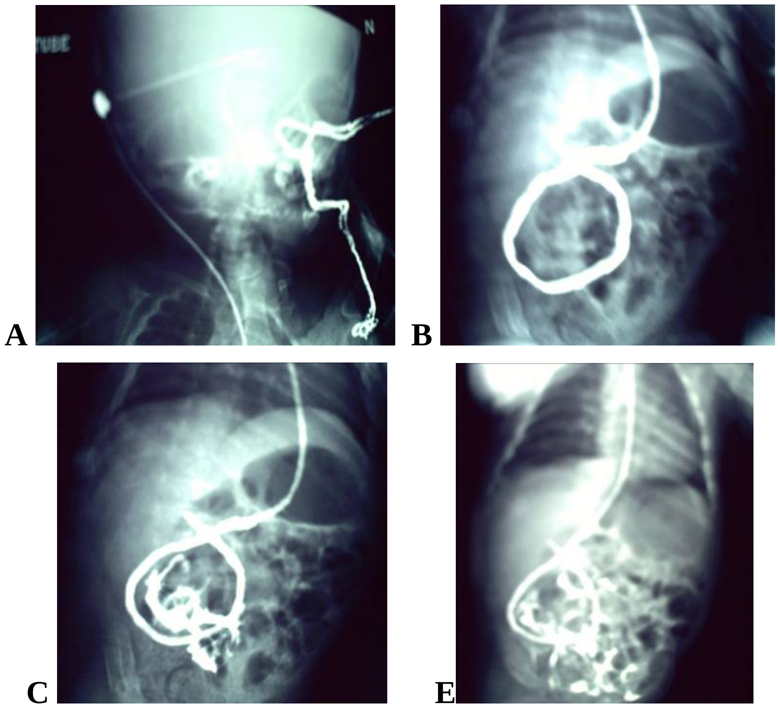

Fig. (6): Case 31: female patient 5 M old, CSF was easily aspirated from reservoir but radiographic shuntogram revealed that free peritoneal spilling occurred late after pumping the reservoir denoting malfunctioning valve.

DISCUSSION

A ventriculoperitoneal or ventriculoatrial shunt is placed for diversion of CSF in the presence of an obstructed ventricular system or normal pressure hydrocephalus. The shunt consists of several components: ventricular catheter, shunt valve, and distal peritoneal or atrial catheter. A ventricular reservoir is occasionally added for CSF access, and angled or straight connection hardware is used to connect the components. The shunt valves are unidirectional check valves, available in several degrees of resistance: low pressure (2–5 cm H_2O), medium pressure (5–9 cm H_2O), and high pressure (10–15 cm H_2O). Medium-pressure systems are the most typical[3].

Ventriculoperitoneal shunt malfunction is a common complication of shunt placement[4]. In one comprehensive actuarial study, the rate of shunt failure after 1 year was 30% and 50% of shunts required some form of revision within 6 years of placement[9]. This may depend on the type of shunt used as well as the location of the ventricular catheter[1]. The confident diagnosis of ventriculoperitoneal shunt malfunction is a difficult and important problem[3]. Shunt malfunction is caused by ventricular catheter obstruction, valve malfunction, distal catheter obstruction, pressure mismatch, or component disconnection. Shunt infection also causes obstruction, most likely as a result of the accumulation of debris within the shunt system. Patients with shunt malfunction present with nonspecific neurological changes, such as fever, headache, nausea, and vomiting. These symptoms clearly overlap with typical viral syndromes[3]. All our patients presented with non specific syndrome of increased intracranial pressure with variable frequency of the initial symptom.

Ventricular catheter obstruction accounts for approximately 40% to 56% of shunt failures, with peritoneal obstruction accounting for approximately 14% to 33%[4]. Multiple site obstruction also occurs. Among our patients Ventricular catheter obstruction accounted for approximately 29% while peritoneal obstruction accounting for approximately 48.4%. Valve obstruction is considered common, but statistics are lacking. Shunt infection is reported to range from 3% to 29%, with an average of 10% to 15%. The frequency of shunt infection appears to be lower in more recent studies, possibly owing to the use of perioperative antibiotics[4].

The radiographic shuntogram is a simple minimally invasive examination that can easily be used to evaluate the flow characteristics of a ventriculoperitoneal or ventriculoatrial shunt. Problems such as ventricular catheter obstruction, valve pressure choice, and distal catheter obstruction can often be separated, aiding the neurosurgeon in targeting the part of the shunt requiring revision. Demonstration of normal shunt function directs the neurosurgeon to seek other causes for the patient's clinical changes[3].

The valvogram was originally introduced by Amador et al in 1969[2] to assess shunt patency in children. With this technique, the ventricular end of the Holter valve system was assessed by gentle CSF aspiration, and shunt obstruction and distal catheter position were evaluated with contrast injection. In early descriptions of the valvogram or shuntogram technique, larger needles (22–23 gauge) were used to enter the valve, and a variable, often large (2–8 mL), volume of ionic contrast material was injected into the shunt system[2,7]. Nonionic contrast material was introduced and recommended with the availability of Dimer-X, since ventricular reflux was occasionally encountered with nonfunctioning incompetent valves[6,7]. Metrizamide has also been used[11]. In our study we used five mL of Iopamidol (Ipemero) as nonionic contrast material

Dewey et al[5] described a more standard approach to the shuntogram technique in children, using 25-gauge needles to avoid valve damage, a 2-mL contrast injection, and specific filming intervals to follow contrast progression in the shunt system. Aspiration of CSF after entering the valve was again used to assess flow from the ventricular component of the shunt. Filming was performed during contrast injection and at 3-minute intervals for up to 9 minutes to follow contrast progression in the distal tubing. In their series, normal shunts were easily aspirated and emptied in 3 minutes. Shunt systems were considered abnormal if aspiration was difficult, if contrast failed to clear within 9 minutes, if contrast failed to clear after pumping the valve, or if an obvious disconnection was present. Shunts were considered questionable if clearing required 6 minutes or longer or if clearing occurred in 3 minutes but other problems, such as kinking, mesothelial sleeve formation, or difficulty with aspiration or injection, were encountered.

Savoiardo et al[10] expanded this technique to include children with Pudenz valves as well as shunts with double-dome reservoirs. They advocated placing only 1.5 to 3 mL of contrast material into the shunt system and emphasized that excessive injection could overcome distal obstruction. Contrast progression was again observed with initial filming, followed by films at 3, 6, and 10 minutes, and by post pump films, if required. If clearing of the peritoneal catheter occurred within 10 minutes, the system was considered normal. If clearing was incomplete at 10 minutes but achieved after valve pumping, flow was defined as slow.

The shuntogram technique has been used in children, but its application in the adult has not been previously described. While the principles of injecting contrast material into the valve and serial filming are similar, Bartynski et al believe interpretation of the shuntogram in adults is different from that in children in away that adult patients with functioning shunts had slow flow rates but did not require shunt revision at the time of evaluation[3]. In children, the normal shuntogram features were established when shunt malfunction was considered in the face of altered mentation but rapid flow of contrast material was documented[2,5,6,7,10,11].

It is important to exclude systemic infection before performing a shuntogram. The radiographic shuntogram offers the ability to isolate the components responsible for malfunction as well as to obtain CSF for culture to exclude shunt infection. The technique offers direct visualization of contrast material and CSF flow. Failure to clear the shunt system after valve pumping absolutely confirms a nonfunctioning system[3].

The cost of a radiographic shuntogram compares favorably with the cost of MR imaging or a nuclear medicine shunt study. The radiographic shuntogram is much faster to perform than the nuclear study and supplies direct visualization of CSF flow and patency. Contraindications to the shuntogram would include systemic infection or a coagulation abnormality. Allergy to contrast material would likely require premedication[3].

In our study complication occurred in one case because of delayed diagnosis of shunt obstruction as radiographic shuntogram was false negative and the patient's vision markedly deteriorated before revision of the shunt was done. But no complications related to the procedure and/ or contrast material. Likewise the other authors reported the absence of complications related to the procedure[3,5,8]. However, Sweeny and Thomas 1987[12] reported several grand mal seizures after the use of metrizamide in one study out of 250 shuntograms.

CONCLUSION

Our opinion favour the use of radiographic shuntogram in the diagnosis of obstructed CSF ventricular shunts as it is simple procedure, minimally invasive and is rapid as well as easy to perform. Its advantage over other methods lies in not only diagnose shunt malfunction but also localize and qualify the malfunction thus it can be used to establish valve malfunction, ventricular or distal catheter obstruction, and peritoneal encystment aiding the neurosurgeon in targeting the part of the shunt requiring revision .

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