ACCSCIENCE PUBLISHING

Advanced Neurology

PERSPECTIVE ARTICLE

Shuntogram technique for diagnosing shunt failure in patients with programmable valves: A literature review and a case scenario

Supplementary File

Table S1. Additional details of the 25 publications on shuntogram technique

Study type	References	Adult or Peds	Indication	Position	Skin preparation	Duration	Contrast agent	Imaging	Patency (CSF pullback)	Diagnosis (negative)	Diagnosis (positive)	Adjusted shunt flow following positive failure	Sensitivity and specificity or result/clearance time
Series	French and Swanson[1]	Peds	Obvious shunt obstruction determined by clinical features and confirmed by CT scan and plain roentgenograms	Initially placed in the supine position	The scalp over the reservoir was clean - shaven, prepared with Betadine (povidone - iodine), and draped	100,000 images over 10 min. Then, at 20 min and 1 h	^{99m}Tc - DTPA , ^{111}In - DTPA	Nuclear - Chicago Pho/ gamma HP scintillation camera	No. 23 needle and syringe were used to penetrate the reservoir through the nicked area. 2 or 3 ml of CSF removed			If spontaneous migration was not demonstrated after 10 min in the supine position, the patient moved to an erect position and immediately rescanned. If no migration occurred over 10 min, the reservoir was pumped to assess the mechanical passage	Accurate if no shunt revision was required for 6 months or if an obstruction was confirmed at an operation after the shuntogram indicated an obstructed shunt
Series	Mirfakhraee *et al.*[2]	Peds	Clinical presentation of shunt malfunction and/or CT documentation of hydrocephalus	Kept in supine position before study, then at study with head in a lateral position	Shaved, prepared, and draped in sterile fashion	Delayed films of reservoir clearance are made between 3 and 9 min.	Metrizamide	X - ray and CT	Small skin incision to prevent the introduction of epithelium. The center of the reservoir was punctured using a 25 - gauge butterfly needle. CSF return noted	In functioning shunts, the reservoir should be clear of any residual contrast material in 3 min.	Persistence of residual contrast material at 9 min and beyond denotes shunt malfunction		One failure in the study with improper technique in puncturing the shunt reservoir
Series	Sweeney and Thomas[3]	Peds	Irritability, vomiting, headache, and pyrexia		Shaved, aseptic technique		Iopamidol		A 23 - gauge butterfly needle is inserted. and CSF is aspirated	If it failed to fill or there was no Rickham reservoir, a needle is inserted into the valve, and contrast is injected into the valve chamber until the distal catheter fills		If no contrast flows distally, the valve is pumped	Errors of interpretation occurred in 16/250 shuntograms. Five false negatives, two false positives. In the remaining nine cases, an abnormality was detected, requiring revision

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Table S1. (*Continued*)

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Series	Benzel *et al.*[4]	Both		Kept in a supine position for 1 h. Ipsilateral shoulder elevated with log roll	Shaved, cleansed, and draped		Metrizamide and iopamidol	Fluoroscopy and CT	If no spontaneous CSF returns following placement of a 25 - gauge needle or after gentle aspiration with the syringe, reposition the needle. If unsuccessful, < 1 ml of water - soluble iodinated contrast may be injected	A contrast agent is injected. This should opacify the distal tubing and spill into the absorptive cavity (i.e., peritoneal cavity) if the distal limb is patent	If no flow is observed, a distal obstruction is present	Overall, a surgical lowering of the shunt drainage pressure was performed in all 22 cases with an abnormal physiologic shuntogram. Eighteen patients improved	Most cases of under - shunting were observed in 21/22 adults. Lowering shunt drainage pressure was performed in all 22 cases with an abnormal physiologic shuntogram. Eighteen patients improved following the procedure, whereas three were unchanged, and one worsened
Series	Vernet *et al.*[5]	Peds	Hydrocephalus with US or CT scan, demonstrating no significant change from baseline	Initially placed in a supine position for a minimal period of 15 min	The scalp over the reservoir was shaved, prepared with iodine, and draped. Reservoir was punctured with a 25 - gauge needle	One frame every other second for 500 sec. Serial views of 60 sec every 5 min for up to 30 min	mCi ^{99m}Tc - DTPA	Gamma scintillation camera	Injected while manually compressing valve transcutaneously to demonstrate ventricular reflux	Ventricular reflux was demonstrated. The entire shunt system was visualized without blockage. Isotope passed uniformly into the abdominal cavity	No migration or loculation was observed around the distal end of the peritoneal catheter	If no migration occurred in the sitting position, a valve was pumped, and shunt patency was reassessed under the camera. In half of the procedures, data were acquired to draw a clearance curve and calculate the clearance half - time of the reservoir	- 14% rate of false - negative results. In most shuntograms, radioactivity diffused in the abdominal cavity by 10 min. The clearance half - time of the reservoir ranged from 1 to 7.5 min

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Series	Bartynski *et al.*[6]	Adult	A shuntogram was performed only after systemic infection was excluded as a cause of the patient's neurologic changes		Shave, Betadine, and Scout images with head turned	Obtained at 3, 6, 9, and 12 min. At 15 min, the shunt valve is pumped 30 times to effect complete clearing of the shunt system, and the final films of all regions obtained	Iohexol	Serial X - ray, filming of cranial, chest, and abdominal components of the shunt	A 25 - gauge butterfly needle. Free backflow when accessed and when withdrawn through a 5 ml syringe	Spontaneous shunt flow was observed when contrast material was seen flowing down the proximal end of the shunt, usually coupled with observation of progressive dilution within the valve	Abnormal shuntogram: (i) CSF not freely withdrawn from valve; (ii) contrast freely refluxes reservoir to the ventricular system; (iii) contrast does not empty from shunt spontaneously, system cleared after pumping valve; (iv) free spillage of contrast into peritoneal cavity not present or inappropriate accumulation of contrast; (v) contrast material cannot be cleared from the tube after pumping		Shunt systems were considered abnormal if contrast failed to clear within 12 min
Series	O'Brien *et al.*[7]	Peds	Recurrent headaches and occasional vomiting, irritability, and lethargy			Every minute for 15 min	^{99m}Tc - DTPA	Fluoroscopy		Negative study: functioning shunt determined by flow to the peritoneal cavity within 15 min and reflux into the ventricle			False negative 14%. The false positive rate was 0%

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Table S1. (*Continued*)

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Series	Vassilyadi *et al.*[8]	Peds	Medical records of all children who underwent shuntograms in a 3 - year period	Supine or prone position with the head turned away from the shunt site	The scalp overlying the valve is slightly shaved, the area prepped using proviodine, and a small sterile drape applied	Every 30 sec, the tracer followed down the shunt. Children kept in the same position. Time of peritoneal spillage, recorded. If there was no peritoneal spill at 20 min, the patients are allowed to sit for 5 min and then re - imaged	^{99m}Tc - DTPA	The tracer is imaged by a gamma camera	A 25 - gauge needle without distal compression. Return of CSF into needle indicates correct puncture and ventricular catheter patency. There is no attempt to actively withdraw any CSF	A normal shuntogram would be one with the spontaneous appearance of CSF within the needle hub and peritoneal spillage within 20 min.	If the shuntogram demonstrated a malfunction and surgery confirmed, with symptoms corrected, or shuntograms showed patency, but the radiologist reported the tracer moved "somewhat slowly"		2/42 normal shuntograms were performed to assess the patency of CSF in asymptomatic patients with fractured shunts; CSF shunt flow seemed patent, and surgery was performed. Ten out of the remaining normal studies were false negative after surgery identified malfunctions (false - negative rate=25%). 17/26 abnormal shuntograms required surgery, and all were confirmed malfunctions (true - positive rate=100%)
Series	Ouellette *et al.*[9]	Peds	A computerized database of patient records was used to identify all shuntograms and CT scans ordered for patients in the ED				^{99m}Tc - DTPA			Patients were presumed not to have shunt dysfunction if they did not present to the pediatric ED 4 weeks after the initial visit	Three independent blinded investigators interpreted imaging modalities as normal. Abnormal definitive diagnoses of shunt dysfunction were all confirmed intra - operatively as the criterion standard		Sensitivity of 92.6%, specificity of 59.5%, positive predictive value of 59.5%, negative predictive value of 92.6%

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Table S1. (*Continued*)

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Series	Thompson *et al.*[10]	Both	Discordant symptoms and radiographic findings (e.g., headache and nausea with radiographically stable ventricular size)	Patients were placed in a semirecumbent position (approximately 45°)	Skin overlying shunt reservoir was prepared with povidone - iodine and alcohol before 2007 and chlorhexidine gluconate and alcohol after 2007	Images from head to pelvis every 15 min for up to 60 min	Approximately 0.5 mCi ^{111}In - DTPA or 1 mCi ^{99m}Tc DTPA in approximately 3 ml CSF or 0.9% NaCl was injected	Philips Bright view XCT or Philips Precedence SPECT/ CT gamma camera system		True negative is defined as a normal shuntogram with at least 30 days of follow - up without a shunt revision	True positive is defined as an abnormal shuntogram with intraoperative confirmation of obstruction		When the "normal" shuntogram included tracer movement into the distal site in<45min,sensitivity to diagnose failure was 37.5% and specificity 97.2%. Conversely, sensitivity was 87.5% and specificity 51.4% when the definition was limited to tracer entry into ventricles and distal drainage within 15 min
Series	Quezada and Grodon[11]	Both	Headache, nausea/ vomiting, and irritability. Must have altered neurologic function	Recumbent position	Prepped with 2% chlorhexidine gluconate and 70% isopropyl alcohol. The dome of the reservoir was punctured with a 25 - gauge butterfly needle	Sequential anterior and posterior images of the head, neck, chest, and abdomen every 15 min for 1 h	99Tc - DTPA	Siemens Intivo SPECT/ CT or Symbia E SPECT dual - head gamma camera system	A 25 - gauge butterfly needle	Rapid ventricular reflux of radiotracer, rapid flow through the distal catheter, and activity within the peritoneum, pleural space, or vascular system	No reflux into the ventricles was reported as proximal obstruction. Very slow distal run - off was reported to be distal obstruction. Extravasation into adjacent tissues was likely due to hardware fracture, tubing disconnection, or improper injection technique		True negative 91%, false negative 8%, true positive 70%, and false positive 30%

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Series	Adamski *et al.*[12]	Both	Symptoms suggestive of shunt malfunction, although imaging studies were stable when compared with baseline scans				Iohexol	Fluoroscopy suite	To assess patency, the peritoneal catheter was occluded using digital pressure just distal to the valve, 21 – 23 - gauge butterfly needle Inserted and contrast slowly injected using live fluoroscopy	A negative shuntogram was defined as no resistance to gentle injection of contrast with normal flow of contrast into the ventricles and peritoneal cavity	Positive shuntogram was defined as resistance to injection of contrast; obstruction of flow involving ventricular catheter, valve or peritoneal catheter, or minimal flow into the ventricles indicating a partial obstruction. Unless there are slit ventricles, lack of spontaneous flow into the needle and tubing is concerning for ventricular catheter occlusion or valve malfunction		Shuntogram sensitivity among the total evaluable patients in this study was calculated at 51.9%, and specificity was measured at 100%

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Case studies	Azimi *et al.*[13]	Peds	Case 1: Tube projecting from the anus; Case 2: Malfunction				Urographic contrast medium	X - ray					Case 1 peritoneal catheter to be in line with the course of the transverse, descending, and sigmoid segments of the colon. Sigmoid colon opacified when contrast injected. At surgery, the peritoneal catheter was withdrawn from the colon, Case 2 showed opacification of a loop of the small bowel. Surgery confirmed small bowel perforation
Case studies	Mannelli *et al.*[14]	Adult	Headache, altered mental status, and somnolence. Development of hydrocephalus				$^{99m}TcO_4$				Demonstrated drainage of the radiotracer through the VP shunt tubing, but with localized collection at the distal tip		CT of the abdomen demonstrates malposition of distal tubing with a tip in the subcutaneous fat. Revision of shunt position with resolution of symptoms
Case studies	Youngberg and Brown[15]	Peds	Increased head circumference				Meglumine diatrizoate	Fluoroscopy					Leakage of the contrast into the right ventricle and onto the cortex. 30 min later developed convulsions

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Case studies	Kazan *et al.*[16]	Peds	i - Intermittent headache ii - Severe headaches and vomiting. Pupils were equal and briskly reactive. Barely responded to verbal or painful physical cues iii - Intermittent headaches, tenderness along the shunt tract iv - Headache, mild hydrocephalus	i - ii - iii - iv -	i - ii - iii - iv -	i - ii - iii - iv -	i - Omnipaque ii - Contrast material iii - ^{99m}Tc radionuclide iv - ^{99m}Tc radionuclide	i - ii - iii - iv -	i - ii - Tapped shunt pump reservoir, removed 20cc iii - iv - CSF removed	i - ii - iii - iv -	i - ii - iii - iv -		i - Radio opaque trace of the valve distal to the skull demonstrated that the SFT was functional, despite slow CSF passage ii - Radio - opaque tracer did not pass into the peritoneum iii - Passage through the SFT into the peritoneum iv - Passing into the tissues surrounding the peritoneal catheter In all four cases, VP shunt revision was performed
Case studies	Gupta *et al.*[17]	Adult	Clear fluid leaking through umbilicus for 3 weeks, and fever with obtundation, hydrocephalus				Iohexol	Fluoroscopy and CT					The fistulous tract from the shunt tube into the umbilicus with contrast seen to be emerging
Case studies	Chang *et al.*[18]	Adult	Dyspnea and pleural effusion in the setting of ventriculopleural shunt			5 min	1 mCi ^{99m}Tc - DTPA			Demonstrated isotope in left pleural space at the tip of shunt			Pleural effusion from patent ventriculopleural shunt
Case studies	Ulus *et al.*[19]	Peds	Cough; chest X - ray revealed hydrothorax in the setting of V/P shunt				^{99m}Tc	Fluoroscopy					Radioactive material injected into the pump was detected in the thoracic cavity during surgery, with CSF draining from the peritoneal end

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Case studies	Lu *et al.*[20]	Adult	Lethargy			0, 15, 30, 60, and 90 min	2 - mCi ^{99m}Tc - DTPA	Fluoroscopy					Cumulative tracer accumulation at the distal portion of the ventriculopleural shunt at the right pleural cavity
Case studies	Kim *et al.*[21]	Peds	Progressive viral - like upper respiratory symptoms, including poor oral intake, intermittent fever, cough, irritability, and an ill appearance.				Radionuclide	X - ray					The radiographic shunt series revealed a radiographically intact VP shunt without migration into the thorax
Case studies	Schmieder & Schraml[22]	Adult	Worsening memory, gait disturbance, and urinary incontinence			5 min	Radiotracer	Fluoroscopy and CT		Tracer to disperse throughout the peritoneal cavity			The antegrade flow of the tracer was seen throughout the shunt tubing and collected just lateral to the shunt tip. Delayed imaging revealed failure of the tracer to disperse throughout the peritoneal cavity
Case studies	Katsevman *et al.*[23]	Adult	Coughing, two episodes of pneumonia, headaches exacerbated by coughing, scapular pain, dizziness, syncope, and intermittent numbness and weakness.			Every 15 min for 45 min	Radiotracer	Fluoroscopy, CT, X - ray, MRI					Good spontaneous flow from the proximal shunt initially, suggesting no proximal obstruction; however, the CSF stopped draining spontaneously

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Table S1. (*Continued*)

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Other	Leveen *et al.*[24]	Neither	Hydrothorax, enlarged heart, and pulmonary congestion				Technetium - labeled albumin microspheres				If the valve system is occluded, the isotope will remain in the abdomen		
Other	Khalatbari & Parisi[25]	Neither	Suspicion of shunt failure in the absence of ventricular enlargement	Lie in a supine position and inactive for up to 1 h before a nuclear medicine CSF shunt study is performed	Aseptically	10 - s intervals for a total of 5 min; these data are used to generate a time - activity curve for shunt emptying half - time	^{111}In - DTPA, ^{99m}Tc - DTPA and ^{99m}Tc - pertechnetate	Anterior static images of the head and neck, followed by anterior static images of the chest and abdomen, were subsequently obtained	A 25 - gauge or butterfly needle is used to aseptically access. 3 - mL syringe to gently aspirate some CSF into the needle hub if spontaneous flow does not occur	Criteria denote normal study findings, typically include the presence of radiopharmaceutical reflux into the ventricle and the appearance of the radiopharmaceutical in the drainage compartment by 15 – 20 min			

Abbreviations: CT: Computed tomography; CSF: Cerebrospinal fluid; DTPA: Diethylene - triamine - pentaacetate; MRI: Magnetic resonance imaging; SFT: Subcutaneous fibrous tract; SPECT: Single - photon emission computed tomography; VP: Ventriculoperitoneal.

References

1. French BN, Swanson ML. Radionuclide imaging shuntography for the evaluation of shunt patency. *Surg Neurol*. 1981;16:173-182.
2. Mirfakhraee M, Benzel EC, Crofford MJ, *et al*. Metrizamide shuntography for evaluation of shunt malfunction in hydrocephalus. *Am J Neuroradiol*. 1985;6(5):815-822.
3. Sweeney LE, Thomas PS. Contrast examination of cerebrospinal fluid shunt malfunction in infancy and childhood. *Pediatr Radiol*. 1987;17(3):177-183.
   doi: 10.1007/BF02388154
4. Benzel EC, Mirfakhraee M, Hadden TA. Evaluation of CSF shunt function: Value of functional examination with contrast material. *AJNR Am J Neuroradiol*. 1991;12(1): 143-147.
5. Vernet O, Farmer JP, Lambert R, Montes JL. Radionuclide shuntogram: Adjunct to manage hydrocephalic patients. *J Nuclear Med*. 1996;37(3):406-410.
6. Bartynski WS, Valliappan S, Uselman JH, Spearman MP. The adult radiographic shuntogram. *AJNR Am J Neuroradiol*. 2000;21(4):721-726.
7. O'Brien DF, Taylor M, Park TS, Ojemann JG. A critical analysis of "normal" radionucleotide shuntograms in patients subsequently requiring surgery. *Childs Nerv Syst*. 2003;19(5-6):337-341.
   doi: 10.1007/s00381-003-0752-y
8. Vassilyadi M, Tataryn ZL, Matzinger MA, Briggs V, Ventureyra ECG. Radioisotope shuntograms at the Children's hospital of Eastern Ontario. *Childs Nerv Syst*. 2006;22(1):43-49.
   doi: 10.1007/s00381-005-1153-1
9. Ouellette D, Lynch T, Bruder E, *et al*. Additive value of nuclear medicine shuntograms to computed tomography for suspected cerebrospinal fluid shunt obstruction in the pediatric emergency department. *Pediatr Emerg Care*. 2009;25(12):827-830.
   doi: 10.1097/PEC.0b013e3181c07461
10. Thompson EM, Wagner K, Kronfeld K, Selden NR. Using a 2-variable method in radionuclide shuntography to predict shunt patency. *J Neurosurg*. 2014;121(6):1504-1507.
    doi: 10.3171/2014.8.JNS132898
11. Quezada JJ, McComb JG. Reliability of the radiopharmaceutical shunt flow study for the detection of a CSF shunt malfunction in the presence of stable ventricular size. *J Neurosurg Pediatr*. 2020;26(4):364-370.
    doi: 10.3171/2020.4.PEDS2020
12. Adamski A, O'Brien MW, Adamo MA. Shuntogram utility in predicting future shunt failures. *J Neurosurg Pediatr*. 2021;28(3):315-319.
    doi: 10.3171/2021.2.PEDS2161
13. Azimi F, Dinn WM, Naumann RA. Intestinal perforation. An infrequent complication of ventriculo-peritoneal shunts. *Radiology*. 1976;121(3 Pt. 1):701-702.
    doi: 10.1148/121.3.701
14. Mannelli L, Monti S, Shin D, Lomabardo I, Behnia F. Subcutaneously obstructed ventriculoperitoneal shuntogram. *Clin Nucl Med*. 2015;40(3):265-267.
    doi: 10.1097/RLU.0000000000000625
15. Brown BR, Youngberg JA. Convulsions folowing a shuntogram performed with meglumine diatrizoate. *Anesthesiology*. 1979;50(1):50.
    doi: 10.1097/00000542-197901000-00011
16. Kazan S, Açikbas¸ C, Rahat Ö, Tuncer R. Proof of the patent subcutaneous fibrous tract in children with V-P shunt malfunction. *Childs Nerv Syst*. 2000;16(6):351-356.
    doi: 10.1007/s003810050530
17. Gupta A, Ahmad FU, Kumar A, Gaikwad S, Vaishya S. Umbilical CSF fistula: A rare complication of ventriculoperitoneal shunt. *Acta Neurochir (Wien)*. 2006;148(11):1205-1207.
    doi: 10.1007/s00701-006-0898-y
18. Chang CP, Liu RS, Liu CS, *et al*. Pleural effusion resulting from ventriculopleural shunt demonstrated on radionuclide shuntogram. *Clin Nucl Med*. 2007;32(1):47-48.
    doi: 10.1097/01.rlu.0000249402.70977.80
19. Ulus A, Kuruoglu E, Ozdemir SM, *et al*. CSF hydrothorax: Neither migration of peritoneal catheter into the chest nor ascites. Case report and review of the literature. *Childs Nerv Syst*. 2012;28(11):1843-1848.
    doi: 10.1007/s00381-012-1862-1
20. Lu YY, Lin WY, Wang HY, Kao CH, Tsai SC. A mass resulting from cerebral spinal fluid collection of ventriculopleural shunt: Radiographic and radionuclide findings. *Clin Nucl Med*. 2013;38(3):215-216.
    doi: 10.1097/RLU.0b013e31827a2518
21. Kim JH, Bauer D, Roberts D. CSF hydrothorax without intrathoracic catheter migration in children with ventriculoperitoneal shunt. *Surg Neurol Int*. 2015;6(12):330.
    doi: 10.4103/2152-7806.161408
22. Schmieder S, Schraml F. CSF-oma identification with nuclear medicine shunt-o-Gram. *Clin Nucl Med*. 2019;44(5): 399-400.
    doi: 10.1097/RLU.0000000000002485
23. Katsevman GA, Harron R, Bhatia S. Shunt-bronchial fistula with coughing up and swallowing of cerebrospinal fluid: rare complication of ventriculopleural shunt. *World Neurosurg X*. 2020;5:100065.

doi: 10.1016/j.wnsx.2019.100065

24. Leveen HH, Vujic I, D'Ovidio NG, Hutto RB. Peritoneovenous shunt occlusion. Etiology, diagnosis, therapy. *Ann Surg*. 1984;200(2):212-223.

doi: 10.1097/00000658-198408000-00016

25. Khalatbari H, Parisi MT. Complications of CSF shunts in pediatrics: Functional assessment with CSF shunt scintigraphy-performance and interpretation. *Am J Roentgenol*. 2020;215(6):1474-1489.

doi: 10.2214/AJR.20.22899