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## Title

Do children with suspected shunt failure also require a radiographic shunt series if a head CT is going to be, or has been, performed?

## Clinical scenario

You are the specialty trainee working in a District General Hospital Emergency Department (ED). A 4-year-old male is presented to the ED by his parents following a 48-hour history of progressive headache and vomiting with lethargy with irritability. His parents report that he was born prematurely and has had a ventriculoperitoneal (VP) shunt inserted. He has otherwise been recently well (at baseline) and there were no signs or symptoms of infection.

You want to obtain head CT imaging before discussing with the neurosurgical team but note that he has had numerous previous ED attendances with several radiographic and head CT examinations. You do not want to exposure the child to unnecessary ionising radiation but are unsure if a radiographic shunt series is necessary if a head CT is going to be performed.

### Structured Clinical Question

Do children with suspected shunt failure (patient) also require a radiographic shunt series (outcome) if a head CT is going to be, or has been, performed (intervention)?

## Search

PubMed and Medline databases on NHS Evidence and Web of Science were searched in May 2020 and the following search terms were used: (child* OR paediatric OR pediatric) AND (((acute AND failure) OR block*) AND ((ventriculoperitoneal OR VP OR V-P OR cerebral) AND shunt) OR hydrocephalus) AND (computed tomography OR CT OR computed assisted tomography OR CAT) AND ((radiograph* OR (x-ray OR xray)) AND shunt AND series). From-11 double screened abstracts (GB and MP), 8 full text papers were extracted and 3 were included in the final commentary (Table 1).

## Commentary

VP shunts are prone to complications with failure rates reported to be up to 50% within 2 years of placement[1] and with up to 87.5% of shunts failing by 10 years.[2] Complications can include infection, obstruction (either intra-abdominal or cranial), and mechanical failure due to component fracture or dislocation.[3] No single symptom is diagnostic of shunt failure[4] which can be life threatening if left untreated.[1 4 5] As such, a timely and accurate assessment of shunt function is required.

The radiographic shunt series (SS) and head computed tomography (CT) both utilise ionising radiation to investigate suspected shunt failure. The SS comprises overlapping anteroposterior and lateral skull, chest and abdominal radiographs which may need to be repeated if suboptimal imaging is obtained due to patient movement. Desai *et al*[6] reported that SS has a poor sensitivity and a significant false-negative in the detection of SF and is even less likely to agree with the findings from other imaging modalities (CT, MRI, NMC) than by chance alone. Scout images obtained when planning head CT examinations may provide comparable images to lateral skull radiographs to evaluate the VP shunt catheter location.[7] When performed for specific indications, single-view site specific radiographs can reduce the number of SS requested by the ED without compromising clinical care: localised swelling or pain along the path of the shunt tubing; externalized shunt tubing from distal erosions (rare); at the request of the neurosurgical team for surgical planning.[7]

Cumulative lifetime exposure to ionising radiation can be significant and should be reduced wherever possible.[8] Infants and children are more vulnerable to the accumulative risks of ionizing radiation than adults[9-11] with an increased risk of developing leukemia or brain malignancy.[12] Head CT examinations are high dose investigations of approximately 4 times the dose of the SS (5.3 mSv and 20 mSv, respectively)[6] but doses will vary by institution, technical parameters and imaging protocol. Moreover, it is reported that children with VP shunts receive a median 8.5 head CT and 3 SS examinations[13] and that children with VP shunts receive a head CT examination in nearly one out of every two ED attendances.[14]

Other imaging techniques and modalities which reduce or obviate exposure to ionizing radiation have been reported: fast-sequence MRI is more cost-effective and definitive for the diagnosis of acute shunt failure when compared with head CT; and sonographic measurement of optic nerve sheath diameter measurement may be a useful initial screening test in children with a low pre-test probability of acute shunt failure.[15-24]

The SS need not been performed when a head CT examination is going to be, or has been, performed in a child with suspected shunt failure. If there is clinical concern for mechanical shunt failure i.e. tubing disconnection, kink or breakage, specific single-view radiographs can be performed.

**Clinical bottom lines**

- The radiographic shunt series should not be used as a first-line investigation for suspected shunt failure [Grade B].
- Single-view radiographs for specific indications may be used if there is a suspicion of mechanical failure following proven shunt failure on cross-sectional imaging [Grade B].

**Table 1.** Summary of evidence

| Citation | Study group* | Study type (level of evidence) | Outcome | Key results | Comments |
|---|---|---|---|---|---|
| Desai *et al*[6] | 238 children, mean age 9.1 years (range 3 months to 17 years) | Retrospective cohort study (level 3b) | To determine the accuracy of plain radiography in diagnosing VP SF in children in whom shunt malfunction is clinically suspected | 16 (6.7%)=catheter discontinuity on SS, of which 6 had CT:<br>4=no SF;<br>2=confirmatory SF<br><br>222 (93%)=normal SS, of which 117 had CT, MRI and NMC, of which:<br>67 (57%)=no SF;<br>50 (43%) confirmatory SF<br><br>SS sensitivity=19.4% (12/62), 95% CI <31%<br><br>SS=10.5% predictive value in demonstrating cause of SF | Majority of SF cases were not detected by SS<br><br>Only evidence of SF on SS was disconnection at the level of the valve at the neck or calvarium<br><br>SS is not advocated as mode of diagnosis in suspected SF<br><br>When SF proven on other imaging, SS may be useful in excluding mechanical aetiology |

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| Miller *et al*[4] | 155 children, mean age 8.1 years (range 0 to 18 years) | Retrospective cohort study (level 3b) | To determine the effectiveness of a shunt evaluation protocol that does not involve routine direct shunt tapping | 373 CT performed, of which 363 had previous CT for comparison<br><br>76/373 (20%)=enlarged ventricles compared to previous<br><br>8/373 (2%)=shunt tubing breakage on SS with normal CT<br><br>5/373 (1%)=sufficient clinical justification for revision without imaging<br><br>46/373 (12%)=unchanged CT or slit ventricles, of which 38 underwent shunt revision<br><br>46/281 (16%)= unchanged ventricular size on CT and intact shunt tubing on SS had non-working shunt at surgery | Normal CT does not exclude shunt obstruction<br><br>Shunt taps may not be needed to assess shunt patency |
| Marchese *et al*[7] | 790 children (274 pre-pathway, 516 post-pathway), age not stated | Prospective comparative study, non-randomised (level 2) | To standardise care and reduce radiation exposure for children and young adults requiring evaluation in the ED for ventricular shunt complications | Implementation of "shunt malfunction" pathway<br><br>Number of SS requested by ED pre- and post-pathway implementation, 62.4% vs 5.32% respectively, $p<0.01$<br><br>Mean reduction in effective dose per ED attendance by 64.6% (95% CI 55.6-73.6, $p\leq0.0001$)<br><br>No radiographs obtained in 45/96 visits (46.9%)<br><br>No change to CT scan utilisation but increased uptake of LD CT protocol with dose reduction of 1.2mSv | Combination of LD CT protocol and focused radiographic projections versus complete SS significantly reduces radiation dose without compromising clinical care |

*All children had suspected shunt failure.
CI, confidence interval; CT, computed tomography; ED, Emergency Department; LD, low dose; MRI, magnetic resonance imaging; mSv, millisievert; NMC, nuclear medicine cisternography; SF, shunt failure; VP, ventriculoperitoneal; SS, shunt series

## Authors


1. George Beattie (Medical doctor, Barnsley Hospital NHS Foundation Trust) [george.beattie@nhs.net]
2. Saurabh Sinha (Consultant Neurosurgeon, Sheffield Children's NHS Foundation Trust) [saurabh.sinha@nhs.net]
3. Suzanne Mason (Consultant in Emergency Medicine, Barnsley Hospitals NHS Foundation Trust & Professor of Emergency Medicine, School of Health and Related Research, University of Sheffield) [suzanne.mason@nhs.net]
4. Daniel JA Connolly (Consultant Neuroradiologist, Sheffield Children's NHS Foundation Trust) [daniel.connolly1@nhs.net]

5. Michael Paddock (Consultant Radiologist, Barnsley Hospital NHS Foundation Trust & Honorary Senior Clinical Lecturer, Academic Unit of Child Health, University of Sheffield) [michael.paddock@nhs.net]

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