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

CLINICAL SCENARIO
You are the specialist trainee working in a district general hospital Emergency Department (ED). A 4-year-old boy is presented to the ED by his parents following a 48-hour history of progressive headache and vomiting with lethargy and irritability. His parents report that he was born prematurely and has had a ventriculoperitoneal (VP) shunt inserted. He has otherwise been well for the past few weeks and there are 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 expose the child to unnecessary ionising radiation. Is a radiographic shunt series (SS) necessary if a head CT is going to be performed?

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

SEARCH
PubMed and MEDLINE databases on NHS Evidence were searched for eligible articles published in English from January 1980 to May 2020. 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). Eleven papers were obtained whose abstracts were double screened (GB and MP). Eight were excluded and the remaining three were tabulated (table 1).

COMMENTS
VP shunts are prone to complications with failure rates reported to be up to 50% within 2 years of placement and with up to 87.5% of shunts failing by 10 years. Complications can include infection, obstruction (most commonly cranial, rarely intraperitoneal) and mechanical failure due to component fracture or dislocation. No single symptom is diagnostic of shunt failure. Shunt failure can be life threatening if untreated; as such, a timely and accurate assessment of shunt function is required. A radiographic SS and a head CT use ionising radiation and both may be used to investigate suspected acute shunt failure. The SS comprises overlapping anteroposterior and lateral skull, chest and abdominal radiographs. The imaging may need to be repeated if suboptimal imaging is obtained.

Desai et al reported that the SS has a poor sensitivity (estimated 19.4%, true sensitivity <31% (95% CI)); a prediction that 10.46% of future SS will be expected to demonstrate the cause of shunt failure; and that the SS is even less likely to agree with the findings from CT, MRI and nuclear cisternography (Cohen’s kappa -0.02) than by chance alone. Thus, they concluded that the SS was not advocated as an acceptable modality in the investigation of suspected shunt failure.

Shunt images obtained when planning head CT examinations may provide comparable images to lateral skull radiographs to determine the VP shunt catheter location and to detect a disconnection from the valve. Further research is required to determine if the diagnostic quality of scout images allows programmable shunt valve settings to be read, obviating the need for formal skull

Table 1 Summary of evidence

| Citation | Study group* | Study type (level of evidence) | Outcome | Key results | Comments |
|----------|--------------|--------------------------------|---------|-------------|----------|
| Desai et al | 238 children, mean age 9.1 years (range 3 months–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 six had CT: 4=not SF; 2=conformatory SF | Majority of SF cases were not detected by SS. Only evidence of SF on SS was disconnection at the level of the valve at the neck or calvarium. SS is not advocated as mode of diagnosis in suspected SF. When SF is proven on other imaging, SS may be useful in excluding a mechanical aetiology. |
| Miller et al | 155 children, mean age 8.1 years (range 0–16 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: 76/373 (20%)=enlarged ventricles compared with previous SS; 373 (2%)=shunt tubing breakage on SS with normal CT | Normal CT does not exclude shunt obstruction. Shunt taps may not be needed to assess shunt patency. |
| Marchese et al | 790 children (274 prepathway, 516 postpathway, 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 | Number of SS requested by ED prepathway and postpathway implementation, 62.4% vs 5.32%, respectively, p<0.01 | Combination of LD CT protocol and focused radiographic projections versus complete SS significantly reduce 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; NMC, nuclear medicine cisternography; SF, shunt failure; SS, shunt series; VP, ventriculoperitoneal.
radiographs. However, single-view site-specific radiographs can reduce the number of SS requested by the ED without compromising clinical care when performed for specific indications: localised swelling or pain along the path of the shunt tubing, externalised shunt tubing from distal migration (rare) and 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 ionising radiation than adults9–11 with an increased risk of developing leukaemia or brain malignancy.12 Head CT examinations are high-dose investigations of approximately four times the dose of the SS (20.0 and 5.3 mSv, respectively),6 but doses will vary by institution, technical parameters and imaging protocol. Moreover, it is reported that children with VP shunts undergo a median of 8.5 head CT and 3 SS examinations,13 and undergo a head CT examination in nearly one out of every two ED attendances.14 Thus, it is incumbent on clinicians to reduce exposure to ionising radiation wherever possible by adhering to the As Low As Reasonably Practicable (ALARP) principle.

Other imaging techniques and modalities which reduce or obviate exposure to ionising 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. Improved access to MRI is required, although several children’s hospitals in the UK are now able to provide this service.24/7. Sonographic measurement of optic nerve sheath diameter measurement may be a useful initial screening test in children with a low pretest probability of acute shunt failure.15–24

Given the small number of tabulated studies (two of which are retrospective) with a low number of participants, there is lack of clarity on the best diagnostic option/pathway. From the available evidence, 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. However, in children with long-term indwelling VP shunts, both the clinical teams and reporting radiologists must remember that the absence of a change in the intracranial appearances does not signify that the shunt is working properly or that there has not been a significant alteration in intracranial pressure. Thus, if there is persistent clinical concern, a neurosurgical opinion is required in order to assess the patient for shunt dysfunction. If there is clinical concern for mechanical shunt failure, that is, tubing disconnection, kink or breakage, specific single-view radiographs can be performed. Further prospective work is needed to robustly answer the clinical question.

_Sponsorship_. The radiographic shunt series should not be used as a first-line investigation for suspected shunt failure (grade C).

_Sponsorship_. 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 C).

**Clinical bottom lines**

► The radiographic shunt series should not be used as a first-line investigation for suspected shunt failure (grade C).

► 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 C).

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