

## Thoughts from the darkroom...

### Is CT of the brain necessary prior to lumbar puncture in patients with suspected meningitis ?

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One of the commonest requests for out of hours imaging is for cranial CT in patients with possible meningitis. Telephone conversations like this may be familiar:

*"Hello I'm the medical SHO on call....I'd like to request a CT brain please...to rule out raised intracranial pressure before lumbar puncture...no we couldn't get a good look at his fundi...they didn't have any tropicamide in A and E...well, perhaps you'd like to do the LP if you don't think a CT is necessary..."*

This type of request in fact may or may not be justified depending on the clinical scenario. The perception of radiologists is that few patients with possible meningitis require head CT before lumbar puncture; the perception of physicians is that the majority do. Pole-positions like this invariably generate conflict between our specialities. Can we use the available literature to guide us to a more evidence-based approach which both groups will find acceptable ?

#### *What's the problem with lumbar puncture anyway ?*

Lumbar puncture was first described by Quincke in 1891. It wasn't until 1909, however, that Harvey Cushing suggested that the presence of a "choked disc" (papilloedema) might predict herniation of cerebral structures following lumbar puncture.

Herniation occurs in two forms. In both cases, shift of cerebral contents occurs due to the development of unequal pressures between intracranial compartments. Uncal herniation refers to movement of the medial portion (uncus) of the temporal lobe into the tentorial notch; this leads to compression of the midbrain, cerebral peduncles and 3rd cranial nerve. Tonsillar herniation, on the other hand, occurs with descent of the cerebellar tonsils through the foramen magnum where they cause compression of the brainstem.

The theoretical mechanism of lumbar puncture-induced herniation (or "coning" as it tends to be called by clinicians) is the lowering of pressure within the spinal compartment by withdrawal of fluid. This, it is imagined, serves to exacerbate any pre-existing inequalities in pressure between cerebral and spinal compartments which may exist

due to cerebral oedema or intra-cerebral mass lesion.

#### *Is herniation a historical rather than a contemporary concern ?*

Some authors have suggested that cerebral or cerebellar herniation as an iatrogenic event should no longer be a significant issue given several changes in practice over the last 100 years. They point to the fact that western institutions will all be using 20 gauge needles or smaller compared to the 16 or 12G needles that were used in the past. Modern needles of the type used for spinal anaesthesia and lumbar puncture cause far smaller holes in the thecal sac and therefore might be expected to result in significantly less leakage of CSF. Advances in microbiological and biochemical analysis have also resulted in a dramatic decrease in the volume of CSF required. This has decreased ten-fold from 30-60ml in the past, to the 3-6ml which we routinely acquire today.

Despite these improvements in practice, there is little doubt that herniation can occur in the context of bacterial meningitis. In a retrospective review of 445 children with confirmed bacterial meningitis published in the BMJ a little under ten years ago, there were 21 episodes of herniation<sup>1</sup>. Eight of these episodes occurred within 3 hours of lumbar puncture and 12 occurred within 12 hours. However, equally noteworthy was the fact that 6 episodes of herniation occurred in children either **prior** to lumbar puncture or **in the absence of puncture at all**. Indeed a majority of reports of herniation in the literature refer to children rather than adults. It may be that children are more susceptible because of comparatively less space around the brain compared to adults who generally have greater "reserve" (sometimes related to atrophy) within the rigid cranium.

#### *Is CT reliable for the detection of raised intracerebral pressure ?*

The belief that CT can be used reliably to detect acute physiological changes in the injured brain is one of the great myths of radiology. Such beliefs were fostered in the early days of CT, often by isolated retrospective case reports.<sup>2</sup> In one well thought out study the relationship between

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anatomical appearances of the brain at CT were correlated with intra-cranial pressure monitoring.<sup>3</sup> This retrospective study was performed in patients with severe closed head trauma and markedly decreased conscious level (GCS<7). The authors observed what they termed "slit ventricles" in 10 cases where there were bilateral and symmetrically compressed ventricles of subnormal size. However, only 4 of these patients actually had any increase in observed intra-cranial pressure and only in one case was this increase thought to be of clinical significance.

More importantly, neither asymmetrical ventricular compression and midline shift nor obliteration of cisterns, fissures or sulci revealed any pattern of correlation with measured intra-cranial pressure. Interestingly, in the study of 445 children referred to earlier,<sup>1</sup> there were 14 occasions on which CT was urgently requested because of clear clinical evidence of herniation at the time of referral – even so, 5 of the 14 scans were judged completely normal.

### Does CT alter management ?

In one prospective trial looking at this question, 41 patients with acute bacterial meningitis underwent both lumbar puncture as well as CT on admission, discharge and at 18 months.<sup>4</sup> Lumbar puncture was deferred in a proportion of patients until raised intracranial pressure was controlled by intubation and hyperventilation (occurred in 4 out of 28 patients with normal scans and 6 out of 15 with abnormal scans – again making the point that level of intra-cranial pressure can not be determined from anatomical images).

The authors comment that clinical management was not influenced by CT findings, *which failed to reveal any clinically significant abnormalities that were not suspected from neurological examination of the patient.* The requirement for CT for the assessment of possible complications of meningitis was also considered. They observed 5 patients who had CT evidence but not clinical evidence of subdural effusions – however none of these patients required treatment for this over and above the treatment for the meningitis itself. Prolonged fever (>9 days) in the absence of neurological signs was not associated with any focal CT abnormality, suggesting similarly that there was no benefit from CT in this situation. They caution that routine CT may lead to over-interpretation of findings; most of their patients showed transient ventricular dilatation in the acute phase – however not one developed progressive hydrocephalus.

### Can we predict the patients for whom CT is unnecessary ?

The remainder of the article will deal with this 'bottom-line' question and focuses on one prospective cohort study in particular, published fairly recently in the New England Journal of Medicine.<sup>5</sup> This study is important because it was prospective in design, involved a reasonable number of patients, and assessed "all-comers" with a putative diagnosis of meningitis on first assessment in the A & E department.

301 consecutive admissions to A&E with suspected

meningitis were assessed. 235 went on to have both CT and lumbar puncture. The main question addressed by the authors was: was it possible to predict on the basis of the clinical presentation which patients would have a normal (and therefore unnecessary) CT head scan ? Patients' condition was scored in a number of areas using a modified National Institutes of Health Stroke Scale.<sup>6</sup> The following baseline clinical characteristics were recorded:

|                                                         |
|---------------------------------------------------------|
| Age > 60                                                |
| Immunocompromise                                        |
| History of CNS disease                                  |
| Seizure within the week prior to presentation           |
| Abnormal level of consciousness                         |
| Inability to answer two consecutive questions correctly |
| Inability to follow two consecutive commands correctly  |
| Gaze palsy                                              |
| Abnormal visual fields                                  |
| Facial palsy                                            |
| Arm/leg drift on motor testing                          |
| Abnormal language                                       |

**Table 1.** Baseline clinical characteristics recorded.

All CT scans were interpreted blind by neuroradiologists who categorised them in one of 3 ways:

- normal (including atrophy only)
- focal abnormality (with or without mass effect)
- non-focal abnormality (with or without mass effect)

Mass effect was defined on the basis of the degree of effacement of the sulci, cisterns and ventricles:

- effacement < 50% = mild
- effacement > 50% = moderate
- effacement > 50% and midline shift = severe

Univariate regression analysis of baseline clinical characteristics was performed with respect to brain appearances at CT scan. The results are summarised in Table 2.

Two facts stand out from this analysis. Three quarters of CT scans were entirely normal whatever the clinical presentation of the patient. Even more importantly, absence of any of the clinical characteristics recorded meant that the CT was normal in 97% of cases. It is this strikingly high negative predictive value which should allow clinical screening to decide which patients genuinely warrant CT. (Of the three patients misclassified, only one had mild mass effect and all three underwent lumbar puncture without complication). Use of screening by

| Presence of any baseline characteristic | Result on CT brain                |          |           |
|-----------------------------------------|-----------------------------------|----------|-----------|
|                                         | Normal                            | Abnormal | Total     |
|                                         | (number of patients (percentage)) |          |           |
| No                                      | 93 (97)                           | 3 (3)    | 96 (100)  |
| Yes                                     | 86 (62)                           | 53 (38)  | 139 (100) |
| Total                                   | 179 (76)                          | 56 (24)  | 235 (100) |

**Table 2.** Prediction of CT appearances by clinical characteristics.

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baseline characteristics would have reduced the frequency of CT by 41% in this study.

Several other messages emerged from this piece of work. There was a significant delay between mean time from presentation to lumbar puncture between those having CT first (mean delay 5.3 hours) and those having just lumbar puncture (mean delay 3 hours,  $p < 0.001$ ). Fortunately this was not mirrored by concomitant delay in antibiotic administration although there was a statistical trend towards significance (mean delay 3.8 vs 2.9 hours,  $p = 0.09$ ). The doctors in the A&E department would have been aware that these times were being audited and this may have resulted in "supranormal" efficiency in antibiotic delivery which would not necessarily be matched in a non-study population.

This was an adult population, perhaps explaining the very low incidence of herniation. Of 289 patients in whom lumbar puncture was performed – including 5 with mild mass effect and 2 with moderate mass effect – not one herniated. The two patients who did herniate and die had *not* had a lumbar puncture at any point in their admission.

### *So, what are the take-home messages ?*

1. **The likelihood of an adult patient experiencing brain herniation in this clinical context is very low.**
2. **Herniation may however occur regardless of**

**whether lumbar puncture is performed.**

3. **CT brain is hopeless at identifying the presence of raised intracranial pressure.**
4. **CT brain is unlikely to alter management in most cases.**
5. **In the absence of the baseline clinical characteristics described, virtually no patient will have an abnormal CT brain.**

### *Where do we go from here ?*

We live and work in an increasingly litigious society where we are all fearful of making the mistake which might harm a patient or damage our careers. An understandable desire to 'cover all bases', however, is resulting in relentless pressure on Radiology departments at a time of a national staffing crisis. This is one area (and there are many others) where a rational evidence-based approach should be employed. Radiologists need to take the initiative in setting up guidelines for imaging. There will, of course, always be circumstances in which variation from such guidelines is required. One solution to this would be to ensure that such referrals are initiated at a senior level, preferably consultant-to-consultant. The development of the field of acute medicine provides the opportunity for such specialists to develop expertise in the identification of those patients for whom imaging is justified. It will be important for radiologists to work closely with acute physicians to ensure the appropriate future use of resources.

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