CLINICAL AUDIT

Role of computed tomography before lumbar puncture: a survey of clinical practice

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Postgrad Med J 2006;**82**:162–165. doi: 10.1136/pgmj.2005.041046

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Submitted 29 August 2005
Accepted
24 November 2005

Introduction: It is becoming increasingly common to request computed tomography (CT) to rule out space occupying lesions before lumbar puncture (LP), even in patients with no clinical signs. Imaging trends within a busy district general hospital in Oxfordshire, UK were analysed with results used to clarify when imaging should be considered mandatory.

Method: A retrospective six month sample was obtained comprising all adults considered for LP. Observed frequencies of abnormal examination findings compared with abnormal investigations were used to determine sensitivity, specificity, positive predictive, and negative predictive values to assess the validity of using a normal clinical examination as a basis for excluding CT.

Results: 64 patients were considered for LP. In total, 58 patients underwent LP, with a single patient receiving two. After an abnormal CT scan, six patients did not undergo a planned LP. In all six of these cases subarachnoid haemorrhage was detected, and in all cases this was considered a probable diagnosis. In no case was an LP precluded by an unsuspected space occupying lesion. Neurological examination showed a sensitivity of 0.72 (0.52 to 0.93), specificity 0.78 (0.64 to 0.91), positive predictive value 0.61 (0.41 to 0.83), and negative predictive value 0.85 (0.73 to 0.97).

Discussion: The high sensitivity and negative predictive values support normal neurological examination as an effective predictor of normal CT scan. This permits the recommendation in cases where subarachnoid haemorrhage is not suspected, a CT scan can be avoided provided there are no abnormal findings on physical or fundoscopic examination.

Computed tomography (CT) is a useful imaging modality, used in a variety of clinical situations. A significant number of CT scans are requested before lumbar puncture (LP), to exclude intracranial abnormality that may give rise to complications.

Natural radiation accounts for an absorbed dose of 2.4 mSv every year.¹ The medical profession accounts for the highest percentage of the artificial radiation to which the population is annually exposed. The bulk of medical irradiation occurs during diagnostic imaging; 50% from CT alone.²

A single CT head scan results in an absorbed radiation dose of 2 mSv, equivalent to eight months' natural background radiation. Although radiotherapeutic procedures have a well reported risk of inducing malignancy, the carcinogenic capacity of diagnostic imaging is more difficult to quantify and limited data are available. Nevertheless it is known that even a single exposure is sufficient to raise the risk of malignancy, which can persist for up to 25 years.³

An increasing reliance on high technology imaging modalities has significant resource implications. Estimates suggest an individual CT scan costs between £80 and £180.² Although raw financial considerations are important, particularly to state funded healthcare providers such as the UK NHS, there are implications for service provision at the local level. An adequate out of hours CT service depends upon access to: an operational scanner; a radiographer qualified to conduct the scan, communication of the images to an appropriately senior radiologist, generation of an accurate report in a timely manner, and finally distribution of that report to relevant clinicians. The provision of one or all of these aspects outside of normal working hours may well be challenging, particularly in smaller regional hospitals.

There is no consensus regarding the use of CT before LP, and the evidence cited as justification for many recommendations is weak.⁶ Box 1 shows some suggested criteria for

further investigation. Note that in cases where subarachnoid haemorrhage (SAH) is suspected, CT is required regardless of other examination findings.

The list in box 1 is subject to some controversy. One widely published textbook states categorically "in general CT should *always* [emphasis original] be carried out prior to LP to exclude an obstructed CSF system or space occupying lesion".⁷

The acquisition of CSF is crucial in the diagnosis of many infective and non-infective conditions. In the context of SAH, centrifugation and photochromatography analysis for xanthochromia has a sensitivity of 98%–100% provided LP is performed at least 12 hours after the event.⁸ It is therefore a useful adjunct in cases where there is a high degree of clinical suspicion but negative CT head scan.

Patient groups who traditionally would not have merited imaging before LP, including suspected meningitis cases, are being increasingly referred for scanning. In one series nearly 80% of patients presenting with meningitis had CT before LP.⁹ Where patients had CT significant delays were found between admission to LP: this group waited on average 2 hours 20 minutes longer for their procedure. Similar trends were identified in timing of antibiotic administration, findings confirmed in other papers.¹⁰

LP is not without risks: post-dural puncture headache is the most common complication, occurring in up to 40% of patients.¹¹ Other complications include epidural or subdural haematoma, infection and, rarely, tumour formation. There have been up to 100 case reports of epidermoid tumours, caused by epithelial cells from the skin seeded within the

Abbreviations: CT, computed tomography; LP, lumbar puncture; PPV, positive predictive value; NPV, negative predictive value; SAH, subarachnoid haemorrhage

Box 1 Considerations before lumbar puncture^{4 5}**Criteria for mandatory CT head scan**

- Signs of raised intracranial pressure (for example, papilloedema, bradycardia occurring with hypertension)
- Changed consciousness (GCS<14)
- Immunosuppression
- Focal neurological deficit
- New onset of seizures
- Suspected SAH

spinal canal space during LP, occurring up to 10 years after procedure.¹²

Perhaps the most serious complication of LP is that of uncal or tonsillar herniation. Typically this occurs within two hours of the procedure and presents with deteriorating consciousness and focal neurological signs. Herniation can occur in patients with normal CSF pressure, thus a normal CT scan does not preclude its occurrence.

METHODS

The Horton General Hospital is a busy district general hospital serving the population of Banbury and the surrounding region of North Oxfordshire, UK. It is one of the smallest district hospitals in England, comprising only four main in-patient medical wards and a total capacity over all specialties of around 200 beds. Laboratory examination of samples is performed both in Banbury and at the John Radcliffe Hospital, Oxford. There are no on-site neurologists in Banbury, the hospital hosting a visiting neurology clinic weekly.

All adults, defined as over the age of 16 on the day of LP, who underwent CSF examination in Banbury from 1 March to August 31 2004 were included in the sample.

The medical records for each patient identified were scrutinised by two independent medical professionals, and data collected under various headings, including demographic information, presenting history, examination findings, and investigation findings.

Data were then analysed using both the criteria presented in box 1, and with reference to published features of SAH, shown in box 2. Cases were thus categorised into those where CT should be considered mandatory (on the basis of any one of the criteria) and those where it was optional. This categorisation was then subject to calculation of Cohen's κ coefficient values as a test of internal agreement.

The sample records were thus analysed by outcome. Data collection was compartmentalised, such that items arising

from the history and examination were categorised before investigation findings, ensuring categorisation could not be biased by prior knowledge of radiological findings. For both normal and abnormal CT scans, each record was categorised by:

- Positive neurological findings only
- Positive CT scan only
- Positive neurological findings and positive CT scan
- No positive findings

The proportions in each category enabled calculation, using published formulas,^{14 15} of sensitivity, specificity, positive predictive values (PPV), and negative predictive values (NPV).

These calculations were performed both on the pooled data (all patients within study) and then repeated for those cases where CT was considered optional. Both sets of data were thus used to determine the validity of using a normal clinical examination as a basis for excluding CT under these circumstances.

RESULTS

During the study period a total of 64 patients were considered for LP, with 58 patients actually undergoing the procedure. One patient had two LPs within the study period, thus generating a total of 59 samples for laboratory analysis. With one exception, all adult LPs were performed by the general medical physicians. The single remaining case was performed by an emergency department physician.

Most patients (39 of 64) were female. Mean age was 41.9 (range 16–83; standard deviation 17.38). A slight majority of total referrals (58.7%) came via the emergency department. Figure 1 shows the referrals grouped by source and month.

In most cases LP was considered to rule out intracranial bleeding ($n = 40$) or intracranial infection ($n = 23$). A single LP was performed to exclude multiple sclerosis.

Physical examination found abnormal neurological findings in 20 patients. Fundoscopy was performed in 45.31% of cases. Abnormal fundoscopic findings were demonstrable in only two patients, in whom both were suggestive of papilloedema. One of these patients had no other abnormal findings on examination.

A total of 528 CT head scans (for any indication) were performed at the request of general medicine or emergency department during the study period. Of these 54 (10.23%) scans were performed as a prelude to LP. Applying the criteria detailed previously, 40 of these scans were considered mandatory. Interobserver agreement was confirmed with a high Cohen's κ coefficient [0.89 (95%CI 0.77 to 1.01)]. There were 18 abnormal scans, but only in six cases was an LP aborted in light of the CT report.

With one exception CT was performed in all patients who met "CT mandatory" criteria. The single exception was a patient presenting with sudden onset headache, hence categorisation to the "mandatory" group, but had features of sepsis including fever in excess of 39°C and raised white cell count. They had no abnormal neurological or fundoscopic examination findings. The LP in this case was normal and there were no complications. A total of 14 "non-mandatory" scans were performed. Table 1 summarises these data in more detail.

Table 2 summarises sensitivity, specificity, NPV, and PPV data for physical examination in the presence of abnormal neurology/fundoscopy findings.

Only five LP results were abnormal, four suggestive of infection. The remaining sample contained oligoclonal bands and was significant in that it was the only abnormal sample arising from a patient with a simultaneously abnormal CT.

Box 2 Summary of diagnostic markers of subarachnoid haemorrhage³

- Severe headache
- Period of unresponsiveness lasting >1 hour
- Sudden onset (seconds to minutes)
- Subhyaloid haemorrhage
- Neck stiffness*
- Vomiting*
- Photophobia*

(*in conjunction with characteristic headache)

Figure 1 Referrals for lumbar puncture, grouped by referral month and source, over the six month study period.

This patient was known to suffer multiple sclerosis before presentation. No samples were xanthochromia positive.

During the audit period there were no complications that could be attributed to CT or intravenous contrast agents. There was a single episode of post-LP headache reported in medical notes, which required autologous blood patching.

DISCUSSION

The intention of this study was to provide an overview of practice in a small district hospital. Practical considerations precluded prospective analysis; however such work has been conducted in this field. A noteworthy paper published in 2000 by Gopal *et al*¹⁰ concludes after large scale investigations that current CT uptake patterns are unnecessarily cautious, recommending that the decisions be left to the individual clinician, aided by certain predictors. The predictors tested were broadly similar to those of this investigation including among others positive examination findings, pre-existing immunosuppressive conditions and/or HIV, known intracranial mass lesion, changed consciousness, or new onset of seizure. Positive examination findings were found to be of crucial importance in predicting radiological abnormality. Of particular note no patient in Gopal's series was found to have an abnormal CT head scan after an unremarkable examination.

The observed frequency of abnormal CT scans in this study is somewhat higher than seen in previous investigations. A recent review of pre-LP CT scans found 25% showed abnormality,⁹ however this investigation was restricted to meningitis cases only and had a lower median patient age. In our study "abnormal" was a loose definition that included any variation from "normal". Many of the anomalies found were not relevant to the contemporaneous presentation, for

example evidence of previous cerebral infarct. It should be noted that although a total of 18 CT scans showed an abnormality, in two thirds of cases this was incidental. If you consider the "CT optional" group alone, a more direct comparator to the review cited above, only 1 in 23 scans (7.14%) was abnormal. A low rate of significant CT abnormality is consistent finding throughout much of the work in this field.^{10 16}

When compared with those patients classified "CT optional", is unsurprising that the "CT mandatory" group patients had higher mean age. The prevalence of both SAH and incidental neurological abnormalities, both definitive criteria for CT, increase with age. This is reflected in the higher proportion of CT abnormalities found in this group.

In no case was LP contraindicated by an unsuspected mass lesion in either patient group. The 14 scans conducted on "CT optional" group patients might therefore have been avoided, with an estimated annual cost saving of £2240 to £5040, or 56 mSv less radiation emitted over 12 months. As six SAHs were diagnosed on radiological grounds the proportion of CT mandatory patients undergoing LP was less than 100%.

In this series, one patient who met "CT mandatory" criteria was referred for LP without having the recommended scan first. They were categorised "CT mandatory" on the basis of a sudden onset headache, however there were clear indicators of sepsis that reassured the admitting physician SAH was unlikely. As noted previously, there were no complications, and the LP result was in fact normal, without evidence of infection or SAH. These actions are consistent with Gopal's conclusions that the judgement of the individual clinician is paramount.

It is a matter of concern that fewer than half of patients being evaluated for LP underwent fundoscopic examination.

Table 1 Comparison of CT mandatory and CT optional groups

Group	Number	Sex (M:F)	Mean age (SD)	CT scans	Abnormal CT results	Lumbar punctures	Abnormal LP results
CT mandatory	41	12:28	43.29 (18.23)	40 (97.56%)	17 (42.5%)	35 (85.37%)	2 (5.71%)
CT optional	23	12:11	37.61 (17.45)	14 (60.87%)	1 (7.14%)	24 (104.35%)*	3 (12.50%)

*One patient had two lumbar punctures performed.

Table 2 Summary of sensitivity, specificity, negative predictive value, and positive predictive value data

Summary of audit point statistics									
	Sensitivity		Specificity		Negative predictive value		Positive predictive value		
Pooled data (includes ?SAH cases)	0.72	0.52 to 0.93	0.78	0.64 to 0.91	0.85	0.73 to 0.97	0.61	0.41 to 0.83	
Selective data (excludes ?SAH cases)	0*	0 to 0	1*	1.00 to 1.00	0.93	0.79 to 1.00	N/A*	N/A*	

*Low frequencies limit statistical analysis.

This is a serious omission as the merits of further investigation before LP in the presence of papilloedema have been well reported. The reasons for such oversights are unclear and as our study was not designed to investigate this no insights are available from the current data. It might be postulated that time pressures or lack of confidence on the part of the assessing clinician are factors contributing to this. It is also possible that the procedure was performed, but not recorded. Medicolegally it would be difficult to justify either case in the event of a complication arising after LP.

The complication rate of both CT and LP was reassuringly low, although one cannot account for complications not requiring medical review, such as mild post-LP headache treated with simple analgesia, as this would not have been specifically recorded in medical notes. Likewise complications that have arisen since the audit was completed, or that were treated in a primary care setting after discharge would be unaccounted for.

As noted previously most investigations were targeted to rule out SAH. The infrequency of positive results should not be taken as evidence to restrict scanning under these circumstances. CT is widely acknowledged as a straightforward, non-invasive, and accurate method of diagnosing this condition. The consequences of a missed diagnosis would be disastrous.

The sensitivity, and in particular NPV, data do however support avoiding scanning in cases where SAH does not enter into the differential diagnosis. A normal neurological and fundoscopic examination is an accurate predictor of a normal CT scan.

These issues are particularly relevant to meningitis cases where treatment delay can have a significant impact on morbidity and mortality. It might suggest the "door to needle" considerations so familiar when applied to thrombolysis might equally apply to meningococcal sepsis. The mean delay to LP seen in other studies where CT was performed was up to 5.3 hours, and this is clearly unjustifiable in such cases.

It is our recommendation that CT can be reasonably avoided provided all of the following criteria are satisfied:

- No suspicion of SAH
- Normal neurological examination
- Normal fundoscopy
- Normal conscious level (GCS 14 or 15)

ACKNOWLEDGEMENTS

The authors are grateful for the assistance received from all staff at the Horton Hospital during the conduct of this study. Deserving of particular thanks are the following: Dr Jonathan Marshall (consultant physician, Horton Hospital); Dr Rolf Smith (consultant physician, Horton Hospital); Dr Penny Hagget (consultant radiologist, Horton Hospital); the staff of the Horton Hospital medical library; the staff of the Horton Hospital medical records department; the staff of the Horton Hospital radiology department.

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Funding: none.

Competing interests: none declared

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