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SPECIAL ARTICLE

Major complications of central neuraxial block: report on the Third National Audit Project of the Royal College of Anaesthetists†

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Background. Serious complications of central neuraxial block (CNB) are rare. Limited information on their incidence and impact impedes clinical decision-making and patient consent. The Royal College of Anaesthetists Third National Audit Project was designed to inform this situation.

Methods. A 2 week national census estimated the number of CNB procedures performed annually in the UK National Health Service. All major complications of CNBs performed over 1 yr (vertebral canal abscess or haematoma, meningitis, nerve injury, spinal cord ischaemia, fatal cardiovascular collapse, and wrong route errors) were reported. Each case was reviewed by an expert panel to assess causation, severity, and outcome. 'Permanent' injury was defined as symptoms persisting for more than 6 months. Efforts were made to validate denominator (procedures performed) and numerator (complications) data through national databases.

Results. The census phase produced a denominator of 707 455 CNB. Eighty-four major complications were reported, of which 52 met the inclusion criteria at the time they were reported. Data were interpreted 'pessimistically' and 'optimistically'. 'Pessimistically' there were 30 permanent injuries and 'optimistically' 14. The incidence of permanent injury due to CNB (expressed per 100 000 cases) was 'pessimistically' 4.2 (95% confidence interval 2.9–6.1) and 'optimistically' 2.0 (1.1–3.3). 'Pessimistically' there were 13 deaths or paraplegias, 'optimistically' five. The incidence of paraplegia or death was 'pessimistically' 1.8 per 100 000 (1.0–3.1) and 'optimistically' 0.7 (0–1.6). Two-thirds of initially disabling injuries resolved fully.

Conclusions. The data are reassuring and suggest that CNB has a low incidence of major complications, many of which resolve within 6 months.

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Central neuraxial block (CNB) techniques can produce highly effective pain relief for a wide variety of indications and may decrease patient morbidity after major surgery, although the extent of the latter benefit is not agreed universally.[1 2] In recent years, both large randomized controlled trials (RCTs)[3] and meta-analysis[2] have led to conflicting conclusions and interpretations regarding the outcome benefit of CNB techniques. However, the risk–benefit analysis must also take into account both the rate of failure of the techniques, which may be higher than some accept,[4] and the incidence of complications.[5–7] In the past, these complications have been serious enough to turn the speciality away from the techniques almost entirely, particularly when reports of paraplegia after spinal anaesthesia in both the USA[8] and the UK[9] led to the near abandonment of CNB in the UK for more than two decades after the Second World War. With the techniques now used widely again, there are reports of, and commentaries on, major complications from both the UK and elsewhere.[10–17] Most recently, Christie and McCabe[18]

†This article is accompanied by Editorial I.

reported a series from one hospital that, with a very high incidence of major sequelae, achieved some prominence.

Knowledge of the incidence of such complications should be an essential component of the clinical decision-making and consent processes, but there are few good data which can be quoted to support such discussions, leaving both patient and clinician in a quandary. Figures (ranging from 1:1000 to 1:100 000) are quoted, but their doubtful validity questions the ability to obtain genuinely informed consent from patients offered these procedures. Recognizing this, and that neither RCT nor meta-analysis is an appropriate method for identifying rare events, the Council of the Royal College of Anaesthetists devoted its third National Audit Project to this topic. The aim was a prospective attempt to identify both numerator (number of major complications) and denominator (number of CNB) information for a 12 month period by a review across the breadth of anaesthetic and pain management practice in the UK National Health Service (NHS). Follow-up (as far as an anonymous reporting system would allow) would extend to 6 months so that final outcome, and incidence, could be assessed and give some indication of the prognosis of such events.

Methods

A two-part project was devised: first, an assessment of the number of CNBs performed annually in the UK NHS (for denominator information); and second, an audit of the major complications of these procedures performed during a 12 month period (for numerator information). Discussions with the Centre of Research Ethics Committees (now National Research Ethics Service) indicated that ethical approval was not required, and the processes involved were agreed with the Patient Information Advisory Group of the Department of Health. The project was advertised widely throughout 2006 and 2007 through direct contact with the relevant organizations in anaesthesia, pain management, neurology, spinal surgery, radiology, and neuroradiology (Appendix 1). The aims and processes of the project were explained and the information was cascaded down to the members of those organizations at regular intervals.

Denominator data

A detailed description of the first part, the 'snapshot' survey (census) to determine denominator information, has been published already,[19] but a brief summary is appropriate here. Between March and September 2006, the anaesthetic department of each NHS hospital believed to be performing surgery was contacted, asked to participate, and to nominate a 'local reporter' (LR) to co-ordinate the project locally. Each LR was asked to collect information on the number of CNBs performed over a 2 week period at the end of September 2006 or an equivalent period at about that time. The blocks were classified as epidurals, spinals, combined spinal–epidurals (CSEs), and caudals for each of the five indications: adult perioperative, obstetric (both labour analgesia and operative delivery), chronic pain, paediatric perioperative, and administered by a non-anaesthetist. We did not request data on CNB that were attempted and failed as we considered it unlikely that all cases would be recorded reliably. For each category, the reporters indicated whether their data were 'accurate', a 'close estimate', or an 'approximate estimate'. The mechanism of data collection was not specified and reminders to return information were sent at regular intervals by post, e-mail, and telephone as necessary. Data were summed to give cumulative totals for a nominal 2 week period and, based on the annual results of one large district general hospital (Royal United Hospital, Bath), these figures were then multiplied by 25 to give an approximation of annual activity.

Event reporting (numerator data)

The same LR system was used to identify complications of CNB, but direct reports from any clinician in all relevant specialities were promoted with the aim of ensuring complete capture of all possible cases. We accepted reports even if the attempted CNB was abandoned: as such, there is a potential to slightly overestimate the incidence of complications because we did not include these attempts in the denominator. The formal audit period was September 1, 2006, to August 31, 2007, inclusive, but reporting was actively encouraged until March 31, 2008, for the same reason. Information was sought on all major complications of CNB with the potential for serious patient harm, including infection, haematoma, nerve damage, and cardiovascular collapse (detailed in Table 1). In addition, because of current concern about wrong route errors (i.e. a drug intended for the epidural or subarachnoid space inadvertently administered i.v., or *vice versa*),[20] reports on these events were encouraged even when no injury occurred.

Primary notification of an event was by e-mail, with reports accepted from any source. The project team was able to exclude obviously irrelevant cases at this stage, but otherwise the LR for the relevant hospital was asked to obtain the details and upload them to a secure, password-protected website (the National Confidential Acute Pain

Table 1 Complications sought in the audit process

Complication	Example
Spinal infections	Epidural abscess, meningitis
Spinal bleeding	Vertebral canal haematoma
Major nerve damage	Spinal cord damage, spinal cord infarction, paraplegia, major neuropathy
Wrong route injection errors	Epidural/intrathecal drugs given i.v. or *vice versa*
Death where the anaesthetic/analgesic procedure is implicated as causal	Cardiovascular collapse, other

Critical Incident Audit, NCAPCIA, www.ncapcia.org.uk). The information requested depended on the type of incident, but the questions were designed to gain a full picture of the procedure and the presentation, severity, and consequences of the complication. The NCAPCIA administrator (D.C.) was able to access these reports and request updates as required, being the only person who knew their source: this was essential to allow requests for clarification and updates of information while maintaining confidentiality. Each case was reviewed in detail by a panel representing all the specialities involved in the project (Appendix 2), and the following details were confirmed:

- type of block and indication for its performance (as described above). Procedures performed for the control of non-operative acute pain (e.g. fractured ribs and pancreatitis) were included in the perioperative group;
- category of complication (Table 1);
- correctness of diagnosis;
- date of CNB within the audit period;
- CNB was performed in an NHS hospital;
- severity of patient outcome (see below), initially and at 6 months (or later where such information was available);
- causation: whether the CNB was the cause of the patient injury: certain, likely, possible, unlikely, and no link.

Severity of complications

Severity of initial and final harm was recorded in a variety of ways. First, it was categorized according to the National Patient Safety Agency (NPSA) severity of outcome scale for patient safety incidents (Table 2).[21] Patient harm was graded as 'temporary' if the incident met the NPSA criteria for moderate injury, and 'permanent' if the outcome was worse than this (severe injury or death). Secondly, where injury was permanent, or assumed to be so, the features were classified as follows:

- sensory only;
- motor: motor weakness of whatever severity, with or without sensory symptoms;
- paraplegia: paraplegia or tetraplegia with or without additional motor or sensory symptoms;
- death: this was classified as 'direct' (e.g. a cervical abscess leading to tetraplegia, respiratory failure, and death) or 'indirect' when the CNB was followed by a series of other events leading to death (e.g. an abscess requiring decompression with good neurological recovery, but complicated by a fatal pulmonary embolism).

Table 2 National Patient Safety Agency severity of outcome scale for patient safety incidents. *First aid, additional therapy, or additional medication. Excludes extra stay in hospital, return to surgery, or readmission. †Return to surgery, unplanned re-admission, prolonged episode of care as in or out patient or transfer to another area such as ICU. ‡Permanent lessening of bodily functions, sensory, motor, physiologic, or intellectual

Grade of severity	Description
None	No harm (whether lack of harm was due to prevention or not)
Low	Minimal harm but necessitating extra observation or minor treatment*
Moderate	Significant, but not permanent harm, or moderate increase in treatment†
Severe	Permanent harm due to the incident‡
Death	Death due to the incident

Interpretation of reports

In a proportion of cases, LRs were not able to provide full details of cases and patient progress, and some information was incomplete in spite of follow-up requests. Therefore, the reports required some 'interpretation' by the review panel, which assumed the worst, unless there was evidence to refute it:

- Diagnosis: where this was uncertain, cases were included: only those with clear evidence of incorrect diagnosis were excluded.
- Causation and outcome: these were particularly difficult to judge in a number of cases, and this led to a decision to quote rates of complications in two ways, that is, in terms of both 'worst' and 'best' case scenarios, defined in the results as 'pessimistic' and 'optimistic' incidences. When causation was judged certain, likely, possible, or unlikely, cases were included in the 'pessimistic' analysis, but those judged as unlikely were excluded from the 'optimistic' analysis. Similarly, efforts were made to determine the patient outcome at 6 months after the CNB. Where outcome at 6 months (or later) was available, this was used in the final judgement, but if such outcome information was only available from an earlier date, that outcome was assumed to have persisted—the 'pessimistic' outcome.
- Thus, the results are presented both cautiously (the 'pessimistic' figures) and pragmatically (the 'optimistic' figures).

Validation of data

Requests were made to several organizations for information which might validate (i.e. confirm the completeness of) both denominator and numerator data. For the denominator, this included the National Joint Registry, the National Obstetric Anaesthesia Database, and the Department of Health Hospital Episodes Statistics. For the numerator, we sought evidence of relevant cases from the NHS Litigation Authority (NHSLA) and National Reporting and Learning Service (NRLS) of the NPSA, the Medical Protection Society, and the Medical Defence Union. Medical journals were checked for reports of relevant cases and authors contacted as necessary. The internet search engine 'Google' was used to search for news items published on the internet with the words (epidural, spinal, death, abscess, haematoma, and infection).

Incidence calculations

Cases were included in the numerator where a complication of CNB led to permanent patient harm and the CNB had been performed within the audit period and in an NHS hospital.

The data were entered into a Microsoft Excel 2007 spreadsheet (Microsoft Corporation, USA) and incidences were calculated (by dividing the numerator for a given group by the relevant denominator). Confidence intervals (CIs) were derived using binomial probability tests with the stat-conf programme (Handbook of Biological Statistics 2008, http://udel.edu/~mcdonald/statconf.html). The primary end-points of the study were the incidences (both 'pessimistic' and 'optimistic') of permanent harm due to complications of the various types of CNB performed within the 1 yr audit period in an NHS hospital. The incidence of decompressive laminectomy in adult patients undergoing a perioperative epidural block was also calculated.

Results

This report focuses primarily on the quantitative aspects of the project. A full report, with expanded clinical details and analysis to identify clinical learning points will be published simultaneously by the Royal College of Anaesthetists (www.rcoa.ac.uk).

By September 2006, all 309 hospitals which had been contacted had agreed to participate and had appointed an LR.

Denominator data (snapshot returns)

The original publication of 'snapshot' data was based on reports from 97% of hospitals,[19] but since then returns have been received from the final 3%. Thus, the denominator data (Table 3) used in the calculation of incidences of complications are based on returns from all the hospitals surveyed, 92% of them grading their figures as 'accurate'. Extrapolating to annual activity by using a multiplier of 25 (see comment above) suggests that a total of just more than 700 000 CNB procedures [~325 000 (46% of total) subarachnoid blocks, 293 000 (41%) epidurals, 42 000 (6%) CSEs, and 47 000 (7%) caudals] are performed annually in the UK. The majority of CNBs were performed for obstetric (45%) or perioperative care (44%) indications.

None of the databases consulted in an attempt to validate these data provided information that could be used for that purpose.

Numerator data (complications reported)

Event returns and validation of completeness

In total, 108 cases were reported directly to the project team or through NCAPCIA, with 84 of these being considered appropriate for panel review. The 24 cases eliminated by the project team before panel review were all minor complications of no relevance to the problems under consideration: when there was the slightest doubt, the cases were included for review.

The NHSLA and NRLS databases were screened by the NPSA for all reports relating to CNB performed in the audit period. This identified ~1700 cases reported to the NRLS (of which 13 were reported to have a serious or fatal outcome) and five cases notified to the NHSLA. The audit lead (T.M.C.) reviewed an unselected subset of 200 of the NRLS cases, all NRLS cases with a serious or fatal outcome, and all NHSLA cases. The NRLS review identified only one case meeting the criteria of the current project (in the 13 serious cases): this had already been reported. Two NHSLA cases were potentially relevant. One (a wrong route injection error) clearly met NAP3's inclusion criteria, but did not match the details of any cases reported at that time. A second case (of nerve injury) possibly met the inclusion criteria, but it was not clear whether it had been reported or not. Both hospitals were contacted by the NPSA and asked to report the case if it met inclusion criteria and had not been reported already. The wrong route injection case was subsequently reported to NCAPCIA and is included with those reviewed in detail.

Review of the literature identified three potential cases for inclusion, but discussion with the authors of the papers indicated that they did not meet the criteria. Internet-based news 'alerts' identified the wrong route injection case also

Table 3 Census phase: estimate of the number of CNB procedures performed annually in 309 UK NHS hospitals (100% return). Figures in parentheses are percentages: in the right column, the percentage of all CNB that were of the type of block of the relevant row, and in the penultimate row, the percentage of all CNB that were performed for the clinical indication of the relevant column. 'Non-anaesthetists' include neurosurgeons, spinal surgeons, orthopaedic surgeons, rheumatologists, 'physicians', and general practitioners. The bottom row indicates the percentage of returns recorded as 'accurate': others were close estimates, or estimates

	Perioperative	Obstetric	Chronic pain	Paediatric	Non-anaesthetists	Totals: block types
Epidural	97 925	161 550	27 975	3125	2475	293 050 (41.4)
Spinal	189 000	133 525	1325	325	775	324 950 (46)
CSE	16 525	25 350	0	0	0	41 875 (5.9)
Caudal	9000	0	11 375	18 050	9125	47 550 (6.7)
Totals: indications	312 450 (44.2)	320 425 (45.3)	40 675 (5.7)	21 500 (3.0)	12 375 (1.7)	707 425 (100)
% Accurate replies	83%	95%	94%	91%	91%	92%

identified by NHSLA screening. Other sources of validation did not identify any further cases.

Sources and timing of reports

Although the methodology of the system meant that anonymous reporting was possible, the majority (67) of cases were from identified individuals: 56 anaesthetists, nine neurologists, and two acute pain nurses. Similarly, other details cannot be described in full, but reports were received from all areas of the UK. Four hospitals reported more than one event, but two of these had neurosurgical units and were reporting complications of CNBs which had been performed elsewhere. It was not possible to obtain detailed information about the dual reports from the other two hospitals.

Events were notified throughout the audit period, but only one was reported after December 2007 and that was in August 2008, 5 months after the formal closure date. However, review indicated that it should be included in the analysis, even at a late stage.

Review panel assessments

Eighty-four cases were reviewed. Thirty-two cases were either performed outside the period of the audit, not performed in the NHS, or the complication did not meet the diagnostic criteria of the audit (wrong diagnosis, no link between CNB and notified complication, or full recovery of the complication at the time it was notified). Fifty-two cases therefore met all of the audit's inclusion criteria and efforts were made to follow-up these cases for a minimum of 6 months (Table 4). All 84 were reviewed for learning points for the clinical report to be published elsewhere (www.rcoa.ac.uk), but the remaining 52 are the focus of this analysis of the determination of permanent injury after CNB. Of these 52 patients, 22 made a fully documented complete recovery from their serious complication (NPSA classification 'moderate', Table 2): seven epidural abscesses, seven nerve or spinal cord injuries, three cardiovascular collapses [requiring cardiopulmonary resuscitation or admission to intensive care (ICU)], three cases of meningitis, one vertebral canal haematoma, and one other (intrathecal opioid overdose leading to respiratory arrest). These cases are not considered further. The remaining 30 events were used in the calculation of the 'pessimistic' incidences of permanent harm after CNB techniques. Detailed review indicated that in 16 cases, the patients were either likely to make a good recovery or the attribution of the permanent harm to the block was tenuous. This left 14 events for the calculation of the 'optimistic' incidences.

Patient characteristics

Events were distributed across both genders and the range of ASA status, with the majority of events occurring after elective surgical procedures and about half the CNBs having been performed by consultants and half by other grades (Table 5). There were no children in the 52 patients in the audit, and the majority of cases occurred in patients aged more than 50 yr. In the 30 patients with permanent harm (judged 'pessimistically'), the complications were spread across all types of CNB: 18 (60%) followed epidural block and seven (23%) spinal anaesthesia. As far as clinical indication was concerned, 25 (83%) were in the perioperative group (Table 6).

Incidence of permanent harm

Considering the overall totals first, the incidence of any permanent injury (NPSA classifications serious and fatal, Table 2) after all CNBs in this survey is 4.2 per 100 000 (95% CI 2.9–6.1; equivalent to 1 in 23 500) using the 'pessimistic' assessment of outcome, and 2.0 per 100 000 (95% CI 1.1–3.3; 1 in 50 500) with the 'optimistic' assessment. However, there was a considerable variation between the incidences after different types of block. In both 'pessimistic' and 'optimistic' assessments, epidural and CSE were associated with higher incidences than both spinal and caudal blocks. Looking at clinical indication also revealed similar variation.

By using the subgroups we used in the census phase (Table 3), it is possible to calculate incidences for each of the subgroups. We report these for completeness (Tables 7–10), but as discussed below caution against

Table 4 Summary of cases reviewed and their classification by review panel. Exclusion from review was due to wrong diagnosis, minor injury, full recovery before notification, and procedure performed outside the dates of the audit or in a non-NHS hospital. See text for definitions of 'pessimistic' and 'optimistic' categories

Category	Total	Excluded from review	Excluded from incidence calculation: full recovery during follow-up	Included: pessimistic incidence calculation	Included: optimistic incidence calculations
Epidural abscess	20	5	7	8	3
Meningitis	6	3	3	0	0
Vertebral canal haematoma	8	2	1	5	4
Nerve injury	18	4	7	7	3
Spinal cord ischaemia	6	2	0	4	0
Wrong route error	11	10	0	1	1
Cardiovascular collapse	6	0	3	3	2
Miscellaneous	9	6	1	2	1
Total	84	32	22	30	14

Table 5 Patient characteristics data of cases reviewed by panel. See text for definitions of 'pessimistic' and 'optimistic' categories. *Based on reporter's data with some interpretation. †Not all data were requested for groups of complications (e.g. operator details were not requested for cardiovascular collapse, wrong route errors, or miscellany)

	Cases included ($n=52$)	Cases with permanent injury (pessimistic interpretation) ($n=30$)	Cases with permanent injury (optimistic interpretation) ($n=14$)
Gender			
Female:male	33:19	17:13	7:7
Age (yr)			
<16	0	0	0
16–50	16	8	3
51–70	17	9	5
>70	19	13	6
ASA grade*			
I–II	33	16	8
III–IV	17	13	5
Not assessed	2	1	1
Surgery			
Major:not major:none	33:11:8	21:5:4	10:2:2
Elective:emergency (total operations)	33:11 (44)	21:5 (26)	11:1 (12)
Site of nursing			
Ward:ICU:died in theatre	11:34:2	16:10:2	10:2:1
Not recorded	5	2	1
Operator for procedure†			
Consultant	27	15	7
Non-consultant-career grade	6	4	2
Specialist registrar	5	3	1
Senior house officer	4	2	0
Not recorded	10	6	4

Table 6 Complications used in calculation of 'pessimistic' (see text for explanation) incidences related to type of block and clinical indication

	Cases	Epidural/ spinal/CSE/ caudal	Perioperative/obstetric/ chronic pain/paediatrics/ non-anaesthetist
Epidural abscess	8	5/2/0/1	6/1/1/0/0
Meningitis	0	0/0/0/0	0/0/0/0/0
Vertebral canal haematoma	5	5/0/0/0	5/0/0/0/0
Nerve injury	7	3/3/1/0	5/2/0/0/0
Spinal cord infarction	4	4/0/0/0	4/0/0/0/0
Wrong route	1	0/0/1/0	1/0/0/0/0
Cardiovascular collapse	3	0/2/1/0	3/0/0/0/0
Miscellaneous	2	1/0/1/0	1/1/0/0/0
Total	30	18/7/4/1	25/4/1/0/0

their over-interpretation. The incidence of complications was highest after perioperative use and considerably lower in other groups (Tables 7 and 8). The incidence of permanent injury after adult perioperative epidural anaesthesia or analgesia was 'pessimistically' 17.4 per 100 000 (95% CI 7.2–27.8; 1 in 5800) and 'optimistically' 8.2 per 100 000 (95% CI 3.5–16.1; 1 in 12 200). Twelve patients in this category underwent decompressive laminectomy (seven for abscess, four for vertebral canal haematoma, and one as a result of nerve injury in association with spinal stenosis), an incidence of 12.3 per 100 000 cases (95% CI 6.3–21.4, 1 in 8100). One patient declined laminectomy.

Paraplegia and death are the worst possible outcomes so figures for these (13 'pessimistic' and five 'optimistic') were extracted and analysed in the same way. The overall incidence of these two complications in this series is 'pessimistically' 1.8 per 100 000 (95% CI 1.0–3.1; 1 in 54 500) and 'optimistically' 0.7 in 100 000 (95% CI 0–1.6; 1 in 141 500) (Tables 9 and 10). The patterns revealed are similar to those seen in the analysis of all permanent complications.

Six patient deaths were reported (two abscesses, three cardiovascular collapses, and one wrong route error). All were included in the 'pessimistic' assessment, giving a rate of <1 in 100 000 (0.8 per 100 000: 95% CI 0–1.8), and three in the 'optimistic' group, a rate of <1 in 200 000 (0.4 per 100 000: 95% CI 0–1.2). Four of the deaths were considered to be directly associated with CNB and two indirectly.

Consideration of the cases with a fatal outcome (Table 11) may clarify how determinations of 'pessimistic' and 'optimistic' decisions were made, and illustrate the need to present the outcome data in both ways.

We followed the progress of those patients reported to the project with an initially serious neurological injury in whom we were able to determine a final outcome (Table 12). Patients were included even if they did not meet inclusion criteria (e.g. incidents occurring outside the audit dates or in private hospitals).

Discussion

The results of this large prospective project are largely reassuring with the incidence of permanent injury being lower than in other equivalent or related studies.[18 22–24] Assessed 'pessimistically' the incidence of permanent injury after CNB was 4.2 per 100 000, and of paraplegia/

Table 7 Incidence of permanent harm (including death) after CNB with 'pessimistic' (see text for explanation) interpretation of data: events per 100 000 cases (95% CI). N/A, zero denominator (i.e. no cases reported in this group in the 'snapshot' phase of the project)

	Perioperative	Obstetric	Chronic pain	Paediatric	Non-anaesthetists	Sum
Epidural	17.4 (7.2–27.8)	0.6 (0–3.4)	0 (0–10.7)	0 (0–95.9)	0 (0–121.1)	6.1 (3.6–9.7)
Spinal	2.6 (1.0–6.2)	1.5 (1.0–5.4)	0 (0–226.1)	0 (0–921.8)	0 (0–386.6)	2.2 (1.0–4.4)
CSE	18.2 (3.7–53.0)	3.9 (1.0–22.0)	N/A	N/A	N/A	9.6 (2.6–24.5)
Caudal	0 (0–33.3)	N/A	8.8 (1.0–49.0)	0 (0–16.6)	0 (0–32.8)	2.1 (1.0–11.7)
Total	8.0 (5.2–11.8)	1.2 (1.0–3.2)	2.5 (1.0–13.7)	0 (0–13.9)	0 (0–24.2)	4.2 (2.9–6.1)

Table 8 Incidence of permanent harm (including death) after CNB with 'optimistic' (see text for explanation) interpretation of data: events per 100 000 cases (95% CI). N/A, zero denominator (i.e. no cases reported in this group in the 'snapshot' phase of the project)

	Perioperative	Obstetric	Chronic pain	Paediatric	Non-anaesthetists	Sum
Epidural	8.2 (3.5–16.1)	0.6 (0–3.4)	0 (0–10.7)	0 (0–95.9)	0 (0–121.1)	3.1 (1.4–5.8)
Spinal	1.6 (1.0–4.6)	0 (0–2.2)	0 (0–226.1)	0 (0–921.8)	0 (0–386.6)	0.9 (0–2.7)
CSE	12.1 (1.5–43.7)	0 (0–11.8)	N/A	N/A	N/A	4.8 (1.0–17.3)
Caudal	0 (0–33.3)	N/A	0 (0–26.3)	0 (0–16.6)	0 (0–32.8)	0 (0–6.3)
Total	4.2 (2.2–7.1)	0.3 (0–1.7)	0 (0–7.4)	0 (0–13.9)	0 (0–24.2)	2.0 (1.1–3.3)

Table 9 Incidence of paraplegia or death after CNB with 'pessimistic' (see text for explanation) interpretation of data: events per 100 000 (95% CI). N/A, zero denominator (i.e. no cases reported in this group in the 'snapshot' phase of the project)

	Perioperative	Obstetric	Chronic pain	Paediatric	Non-anaesthetists	Sum
Epidural	6.1 (2.2–13.3)	0 (0–1.9)	0 (0–10.7)	0 (0–95.9)	0 (0–121.1)	2.0 (1.0–4.5)
Spinal	2.1 (1.0–5.4)	0 (0–2.2)	0 (0–226.1)	0 (0–921.8)	0 (0–386.6)	1.2 (1.0–3.2)
CSE	12.1 (1.5–43.7)	0 (0–11.8)	N/A	N/A	N/A	4.8 (1.0–17.3)
Caudal	0 (0–33.3)	N/A	8.8 (1.0–49.0)	0 (0–16.6)	0 (0–32.8)	2.1 (1.0–11.7)
Total	3.8 (2.0–6.7)	0 (0–0.9)	2.5 (1.0–13.7)	0 (0–13.9)	0 (0–24.2)	1.8 (1.0–3.1)

Table 10 Incidence of paraplegia or death after CNB with 'optimistic' (see text for explanation) interpretation of data: events per 100 000 (95% CI). N/A, zero denominator (i.e. no cases reported in this group in the 'snapshot phase' of the project)

	Perioperative	Obstetric	Chronic pain	Paediatric	Non-anaesthetists	Sum
Epidural	1.0 (1.0–5.7)	0 (0–1.9)	0 (0–10.7)	0 (0–95.9)	0 (0–121.1)	0.3 (0–1.9)
Spinal	1.1 (1.0–3.8)	0 (0–2.2)	0 (0–226.1)	0 (0–921.8)	0 (0–386.6)	0.6 (0–2.2)
CSE	12.1 (1.5–43.7)	0 (0–11.8)	N/A	N/A	N/A	4.8 (1–17.3)
Caudal	0 (0–33.3)	N/A	0 (0–26.3)	0 (0–16.6)	0 (0–32.8)	0 (0–6.3)
Total	1.6 (1.0–3.7)	0 (0–0.9)	0 (0–7.4)	0 (0–13.9)	0 (0–24.2)	0.7 (0–1.6)

death was 1.8 per 100 000. 'Optimistically' the incidence of permanent injury was 2.0 per 100 000 and of paraplegia/death 0.7 per 100 000. The incidence of complications of epidural and CSE were at least twice those of spinals and caudals.

Previous studies have focused on the neurological complications of CNB, but this project took a broader approach and included all major complications of CNB, whether leading to neurological or other major sequelae. As a result, several deaths and major complications from wrong route errors or cardiovascular collapse were identified.

An internal NPSA paper describes epidural anaesthesia and its multiple potential complications well: 'a complex amalgam of clinical judgement, technical skills, materials and equipment, drug delivery systems, patient supervision and care pathways. In addition to inherent complications in the procedure, each of these facets has the potential to generate patient harm through a combination of patient characteristics, human error or shortfalls in performance, equipment dysfunction and broader system failures. As a consequence, an enormous number of injuries can result'.[25] This description is applicable to all forms of CNB and encapsulates the complexity of these seemingly simple procedures. The results of this national project reflect the complexities of both CNB and the interpretation of its sequelae.

Data interpretation

The data contain both clinical uncertainty and statistical uncertainty. We have presented the results in both 'pessimistic' and 'optimistic' terms to acknowledge the clinical uncertainty. As the case descriptions of the patients who

Table 11 Case summaries of deaths due to CNB

Death 1	A middle-aged patient with locally advanced and metastatic malignancy underwent a very prolonged urological procedure under spinal anaesthetic. No senior anaesthetist was present. Moderate hypotension progressed to profound hypotension with no recordable arterial pressure. Attempted resuscitation, involving senior members of staff, was unsuccessful. The death certificate recorded acute myocardial infarction as the cause of death. The case was included in the pessimistic and optimistic incidences and death was considered a direct complication of CNB
Death 2	A very elderly frail patient had a joint arthroplasty performed under CSE and was nursed on ICU after operation. During a period of hypotension, a large volume of bupivacaine was inadvertently administered i.v. The patient developed pulseless electrical activity and prolonged resuscitation failed. An inquest recorded a verdict of accidental death. The case was included in the pessimistic and the optimistic incidence of permanent harm. Death was considered a direct complication of CNB
Death 3	A healthy elderly patient underwent a lower limb arthroplasty. The epidural component of a CSE was complicated by an inadvertent dural tap. Anaesthesia was uneventful. A low-dose local anaesthetic infusion was commenced via the epidural catheter and several hours later, the patient was found in cardiac arrest. Routine observations had not been performed for several hours. The patient was resuscitated and admitted to ICU, but major neurological damage was evident and the patient died several weeks later. The case was included in the pessimistic and optimistic incidence and death was considered a direct complication of CNB
Death 4	An unfit elderly patient was due to undergo repair of a fractured neck of femur. Spinal anaesthesia was performed. Approximately 12 min later, the patient collapsed and resuscitation was unsuccessful. Information on this case was grossly incomplete. There was also uncertainty as to what led to the patient's death: potential causes included drug allergy, thromboembolic, or fat embolus and complications related to the spinal anaesthetic. The case was included in the pessimistic incidence and excluded from the optimistic incidence. Death was considered a direct complication of CNB
Death 5	An elderly unfit patient underwent a caudal injection for chronic back pain. Recovery was uneventful. Several days later the patient presented with sepsis, and an epidural abscess (distant from the procedure site) was identified. 'Unrelated complications during hospital admission' led to ICU admission. The patient made a good recovery from these, but then suffered an unexpected fatal cardiac arrest. The chain of events that culminated in patient death started with the caudal block, but the chain of causation is far from clear. The case was included in the pessimistic and excluded from the optimistic incidence of permanent harm. Death was considered an indirect complication of CNB
Death 6	An elderly patient with multiple medical co-morbidities and immunosuppression was admitted to ICU after a respiratory arrest. The patient had vertebral collapse and uncontrollable back pain. Use of parenteral opioid analgesia before ICU admission had led to pneumonia and respiratory arrest. After discussion, an epidural was inserted leading to good analgesia. Within 24 h, the patient developed leg weakness and subsequent investigation identified an epidural abscess. Surgery was offered and declined. The patient developed paraplegia and was discharged, wheelchair-bound, at 6 months. The patient died an indeterminate period of time later. There was doubt as to whether the abscess pre-existed the epidural. There was also uncertainty as to what led to the patient's death. The case was included in the pessimistic incidence and excluded from the optimistic incidence. Death was considered an indirect complication of CNB

Table 12 Prognosis, at 6 months, of all significant injuries with early neurological injury after CNB: numbers (%). Cases include those occurring after CNB performed outside the audit period or in non-NHS hospitals. Immediately fatal cases are not included

	Cases reported with initial neurological impairment	Major improvement	No or minimal improvement
Ischaemia	5	0 (0)	5 (100)
Abscess	12	7 (58)	5 (42)
Nerve injury	13	9 (69)	4 (31)
Meningitis	3	3 (100)	0 (0)
Vertebral canal haematoma	8	6 (75)	2 (25)
Total	41	25 (61)	16 (39)

died illustrate, in many cases, the interpretation of clinical descriptions was difficult because causation may be uncertain within a complex train of events. In other cases, the degree to which CNB led to final outcome may be uncertain. As an example we do not know whether spinal cord ischaemia after general anaesthesia in elderly frail patients who also have an epidural in place is caused by the CNB or simply coincidental: there were four such cases. Further, the final outcome was not always clear. One option would have been to be more decisive and simply present one 'best guess' result, but this would be an inappropriately simplistic response to the reality of complex clinical data. In 11 of 84 cases, interpretation was hampered by incomplete information: gaps were interpreted pessimistically even though this may mean that some patients were included inappropriately.

The statistical uncertainty is accommodated by the use of 95% confidence intervals (CIs) for all calculated incidences. In many cases, CIs are large, an inevitable consequence of the low or zero numerators of some groups. The data with the narrowest CIs are those with larger numerators and large denominators. Data with low or zero numerators are difficult to interpret.[26 27] For zero numerators, we used the recommended 'rule of 3' (which states that for n observations with a zero numerator, the upper 95% confidence limit is $3/n$) to calculate the upper confidence limit.[26] The importance of this is that the main results have quite narrow CIs (e.g. pessimistic incidence of permanent injury from any CNB; 4.2 per 100 000 cases, 95% CI 2.9–6.1). In contrast, some of the subclassifications of the data have very wide CIs (e.g. optimistic incidence of death or paraplegia after spinal anaesthesia in children 0 per 100 000 cases, 95% CI 0–921.8). This makes such data, particularly those with zero numerators, very difficult to interpret, and we would advise extreme caution in doing so.

The nature of this project means that whatever incidence is calculated from our data, it can only be a *minimum* incidence: unreported or wrongly excluded cases would increase the rates. Each additional case would increase the pessimistic incidence by ~3%.

Data reliability and validation

The first and most obvious question is, 'are the results robust?' We consider the denominator(s) to be robust because they are based on a census of activity of the entire

relevant population not a sample. All UK NHS hospitals committed to the project and all returned census data with more than 92% of these data being reported as 'accurate'. Therefore, any error in the denominator is small.

Within the numerator data, there are both 'known unknowns' and 'unknown unknowns'.[28] The known unknowns are those cases which were reported, but where detail was inadequate for robust decisions on the nature or outcome of the event. In 11 cases (13%), insufficient information prevented determination of long-term outcome: in each, no recovery was assumed. Therefore, several cases have been classified 'pessimistically' as suffering permanent injury when full recovery may have occurred: this will have increased the resulting incidence of such complications. The unknown unknowns are those cases which may exist, but were not notified and therefore have not been included in incidence calculations. Inevitably, it is impossible to determine their number and futile to speculate on numbers, but every effort was made to disseminate widely information about the project, both within and outside the anaesthetic speciality. That 100% of hospitals volunteered an LR to the project, 100% returned census data, and more than 10% of cases were notified by non-anaesthetists attests to wide awareness and enthusiasm for the project.

Several sources were searched in an effort to validate the denominator (the number of procedures performed annually) and numerator (the number of relevant complications). These sources were either incomplete, from different populations, not validated themselves, or were impossible to correlate with the data presented here. None of the sources searched provided any information which conflicted with this project's data. Validation attempts showed that most cases of significant injury after CNB had not been notified to other national databases of clinical incident (e.g. NRLS). This raises concerns over the current under reporting of serious clinical incidents to the NRLS. It is, however, recognized that a number of data sources are required to fully capture and characterize clinical incidents.[29] In contrast, validation attempts only identified one case that had, at that time, definitely not been reported to us and we subsequently learned of this case by other means also.

In spite of the inability to validate data externally, comparisons are possible with other data published recently. A UK audit of more than 10 000 paediatric epidurals reported a similarly low number of major complications, no deaths, and a permanent neurological injury incidence of 1 in 10 663,[30] and thus is consistent with this survey. A survey of UK hospitals by Meikle and colleagues,[31] identified knowledge of 40 vertebral canal haematomas occurring in a 6 yr period. Their annual rate of seven cases per year is very similar to that of this project: eight cases of vertebral canal haematoma were reported in 1 yr, with five meeting full inclusion criteria. In a Canadian series, the rate of decompressive laminectomy was 21 per 100 000 cases.[32] In our equivalent subgroup (adult, non-obstetric perioperative epidurals), the incidence of decompressive laminectomy was 12.3 per 100 000: within the confidence limits of the Canadian data. It should be noted that Canadian and UK practice in selecting patients for laminectomy may well differ and our cohort contains nine cases which might have undergone laminectomy if the threshold for it was lower.

Comparison with other studies

The burden of neurological complications from CNB compared with other causes such as general anaesthesia and surgery is not well reported. A recent review of 54 cases from a UK medical defence organization found 72% were 'surgical' and 28% 'non-surgical'.[33] This, somewhat limited report indicates that neurological injury associated with regional anaesthesia is much less frequent than that related to surgery. Further, the incidence of such injury may differ little between regional and general anaesthesia.[34]

The best information available previously on major complications after regional anaesthesia comes from surveys in two Scandinavian countries, Finland and Sweden, both having 'no fault' compensation schemes and populations small enough to allow for central reporting systems. In Finland, a survey of 720 000 procedures performed between 1987 and 1993 found that the incidence of major complications was one in 22 000 after spinal anaesthesia and one in 19 000 after epidural block.[22] In Sweden, a survey of 1.7 million procedures performed between 1990 and 1999 found an incidence of severe neurological complications of one in 20 000–30 000 after spinal anaesthesia, one in 25 000 after obstetric epidural, and one in 3600 after non-obstetric epidural.[23] Both reviews were retrospective.

In the UK, Christie and McCabe[18] retrospectively recorded 12 major complications after 8100 perioperative epidurals (1 in 675) in one hospital. This approximates to 148 per 100 000 epidurals. As nine patients made a full recovery, permanent injury was three in 8100 (37 per 100 000, 95% CI 7.6–108). Our point estimates for permanent injury after adult perioperative epidural are: pessimistic 17.4 per 100 000 (95% CI 7.2–27.8) and optimistic 8.2 per 100 000 (95% CI 3.5–16). Although the CIs from these data are narrower than those of Christie and McCabe, there is significant overlap. The figures reported here come from a population some 12 times larger so that the point estimates and CIs are likely to be more robust.

Cameron and colleagues[35] reported a similar, retrospective, single hospital series, from Australia. Two vertebral canal haematomas and six epidural abscesses followed 8210 'acute pain' epidurals. One laminectomy was required and there were no cases of permanent neurological injury. The incidences of vertebral canal haematoma (24 per 100 000, 95% CI 3–88), abscess (73 per 100 000, 95% CI 27–159), laminectomy (12 per 100 000, 95% CI

1–68), and permanent neurological harm (0 in 100 000, 95% CI 0–45) are again broadly consistent with those reported here.

Clinical implications

In the current series, as in the Swedish study, most complications of CNB occurred when epidural block was used in the perioperative period. Whether this was because it was used in higher risk patients is not something that this project can identify, but a higher (or lower) incidence of complications in one subgroup does not necessarily equate to the procedure being less (or more) appropriate for them. There are both statistical and clinical reasons for this. First, Moen and colleagues'[23] figure of one in 1800 major complications in women having epidural anaesthesia for knee arthroplasty is often quoted, but the absence of any complications in men having the same procedure for hip arthroplasty or spinal anaesthetic for knee arthroplasty is rarely mentioned. Denominators for these groups were as low as 7000 and are too small for robust point estimates of incidences.

Secondly, the clinical perspective of the appropriateness or safety of a CNB procedure must recognize the potential benefits of that procedure (compared with other techniques) and risks other than the major ones reported here. Such risk–benefit analyses will differ between subgroups of patients and procedures so, for both statistical and clinical reasons, comparisons between subgroups should be made with considerable caution.

The patient characteristics are also relevant. More complications were reported in females than in males, but permanent injury was of equal incidence. Although many patients experiencing complications were aged >70 yr, a significant proportion was <50 yr of age (Table 5). More than half of the patients were fit and well (estimated ASA grades I–II), and most patients were undergoing major, elective surgery with CNB being performed by consultants. However, denominator data for these observations were not collected, so the extent (if any), to which these factors are associated with, or causal of, adverse outcomes cannot be determined. Notwithstanding this, patients who developed spinal cord ischaemia, vertebral canal haematoma, and epidural abscess were usually elderly, many were infirm and most undergoing major surgery. In contrast, patients suffering (non-ischaemic) nerve injury were more frequently young and healthy. These differences reinforce that comparisons between subgroups may not be valid.

Accepting these cautions, several clinical findings are of note. More complications occurred with perioperative epidural than in any other subgroup, although the four perioperative deaths all occurred in association with spinal or CSE block. Obstetric, chronic pain, and paediatric groups had a low incidence of major complications. This series includes one of the largest cohorts of each subgroup and, as such, those results are reassuring.

Concerns have been raised previously about the safety of CSE,[36–38] and in this series, it had a relatively high incidence of complications. It represented only 5.9% of all CNBs performed, but led to 13–14% of permanent injuries and 15–40% of cases of paraplegia/death. Two of the deaths followed its use.

Of perhaps greater concern is the continuing problem with 'wrong route' injection errors: nine cases are reported here, six in obstetric practice. There was one death, but no other patient harm. A further similar death occurred in an obstetric unit shortly before this audit started:[16] judged by the coroner to be an 'unlawful killing'.[39] Subsequently, an NPSA-published safety alert[20] and multi-professional best practice guidance[40] have highlighted the problem and identified measures to reduce its occurrence. That one in four respondents to a recent survey of 206 UK obstetric units reported knowledge of such an event indicates that this may be a major problem.[41] Several alternatives, to remedy these potentially fatal mix-ups, have been advocated, but until a robust solution is universally in place, these events are likely to continue. This might be termed a national 'systems error'. It is beyond the remit of this review to evaluate solutions, but clearly one must be found.

Prognosis of neurological complications

Most reviews of serious complications of CNB do not report their prognosis. All major complications are important, but the incidence of permanent harm is the most critical outcome. In Christie's series, three-quarters of identified patients made a full recovery. In this project, it was possible to monitor the progress of 41 initially major neurological complications of CNB (Table 12), and in 25 (61%) complete, or almost complete, recovery was documented. Neurological injury associated with spinal cord ischaemia or vertebral canal haematoma had a notably poor prognosis, whereas all patients with meningitis and the majority of patients experiencing nerve injury and abscess recovered fully. As we did not set out to identify all mild or moderate complications of CNB, unreported minor cases will have occurred and some may have resulted in permanent harm.

Overview

This project attempted to identify the incidence of major complications resulting in permanent harm after CNB in NHS hospitals in the UK. The number of such procedures was estimated in a 2 week census, and the complications of all CNBs performed over 1 yr in the NHS were identified, followed up, and analysed in detail. Analysis of the data suggests a lower incidence than reported previously in other series, usually of smaller numbers of patients, but there can be no certainty that all relevant cases were identified. There would need to be a considerable number of additional cases for the results of this project to be changed significantly, but if anyone is aware of such an

unreported case meeting the inclusion requirements (see Methods section), the review panel would welcome further reports (in confidence to Professor Wildsmith at jaww@-doctors.org.uk). If a substantial number of reports is made, the results will be updated in the future.

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Appendix 1: supporting organizations

The project was endorsed by the following organizations and specialist societies which played an important role in the promotion and dissemination of information about the project: Association of Anaesthetists of Great Britain and Ireland, Association of British Neurologists, Association of Paediatric Anaesthetists, British Association of Spinal Surgeons, British Pain Society, British Society of Neuroradiologists, European Society of Regional Anaesthesia (Great Britain and Ireland Section), Medical Defence Union, Medical Protection Society, National Confidential Acute Pain Critical Incident Audit, National Patient Safety Agency, Obstetric Anaesthetists Association, Royal College of Radiologists, and Society of British Neurological Surgeons. The project was also endorsed by the Chief Medical Officers of England (Sir Liam Donaldson), Northern Ireland (Dr Elizabeth Mitchell), Scotland (Dr Harry Burns), and Wales (Dr David Salter).

Appendix 2: the review panel

The review panel was composed of experts in CNB and its complications, as follows (in alphabetical order with their nominating groups): Dr David Bogod (Obstetric Anaesthetists Association), Dr Iain Christie (Association of Anaesthetists of Great Britain and Ireland), Dr David Counsell (National Confidential Acute Pain Critical Incident Audit), Dr Max Damian (Association of British Neurologists), Dr Barrie Fischer (European Society of Regional Anaesthesia: Great Britain and Ireland Section), Dr Richard Howard (Association of Paediatric Anaesthetists), Professor Ravi Mahajan (Royal College of Anaesthetists), Dr Angelique Mastihi (Medical Protection Society), Mrs Anne Murray (Patient Liaison Group, Royal College of Anaesthetists), Mrs Joan Russell (National Patient Safety Agency), Dr Nick Scott (European Society of Regional Anaesthesia: Great Britain and Ireland Section), Dr Andrew Vickers (British Pain Society), Professor Tony Wildsmith (Royal College of Anaesthetists). Several panel members also brought medico-legal expertise to the review panel. The panel was chaired by Dr Tim Cook (Project Lead, Royal College of Anaesthetists) who obtained additional expertise, as required, from individuals nominated by specialist micro-biological or radiological organizations.

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BJA

Correspondence

Major complications of central neuraxial block: the Third National Audit Project: some comments and questions

Editor—The Third National Audit Project (NAP3) is the largest prospective study regarding the incidence of complications after central neuraxial blocks (CNBs) performed.[1] All collaborators are to be congratulated with the success of this ambitious project. The numbers of patients and complications included are considerable, and highly reliable information was obtained.

Unfortunately, the impact of the results might be reduced by their presentation. Obstetric patients, well known to constitute a low-risk group, are included in the denominator, predictably reducing the incidence of complications. In accordance with the endpoints of the study (permanent damage or death), successfully treated complications are excluded from statistics presented in the abstract (and press release), also contributing to a lower incidence of complications. However, patient outcome is dependent on vigilance and suspicion of a complication, in turn largely based on the perceived probability of such a complication arising. The present study illustrates this relationship, as permanent damage in many cases might have been avoided by more timely action. Subgroup analysis of patient groups at higher risk for complications is therefore of great value.

The next step, risk–benefit analysis, has recently been performed in well-defined patient categories. Some studies show questionable benefits of perioperative epidural blockade (EB), as in cardiac patients and after liver resection,[2 3] in spite of the fact that in these patient groups, the acceptable risk level is much higher than the risk level acceptable to the obstetric patient requiring pain relief during labour. This difference is another argument in favour of separating obstetric CNBs from all remaining CNBs.

The distinction of outcomes as 'optimistic' or 'pessimistic' introduces a new dimension of difficulty in the preoperative colloquium. The prospect of an operation without neurological damage 'following uneventful CNB' when compared with 'following complicated CNB but with successful laminectomy' to most patients probably sounds like two altogether different stories, leaving the patient with an impossible choice.

During the 1990s, it was believed that the higher incidence of vertebral canal haematoma (VCH) in the USA was caused by thromboprophylaxis with higher dosage of low-molecular-weight heparin compared with European countries. The lower incidences in Europe were calculated from case reports in the literature and assumed numbers of blocks.[4] The high incidence of VCH in the USA was confirmed in our study in Sweden.[5] Recalculating our results for comparison with NAP3, the incidence of VCH after non-obstetric perioperative EB was 1:10 200, compared with the incidence of 1:19 500 in the NAP3. Female orthopaedic patients constituted a high-risk group in the USA and in Sweden, in our study with an incidence of VCH as high as 1:3800. The NAP3 does not define numbers of orthopaedic EB, and it is unclear whether the use of orthopaedic EB has diminished in the UK, as it undoubtedly has in Sweden, after the results of these studies.

The discrepancy of complications in obstetric *vs* orthopaedic patients is important not only for the application of CNB in everyday clinical practice, but also for the understanding of the pathophysiology of the complications. Specific pathology and non-specific age-related processes cause narrowing and closing of the vertebral canal.[6 7] Consequently, in the case of VCH in an elderly patient, the volumes causing symptomatic compression may be inferior to those injected performing a blood patch for treatment of post-dural puncture headache in the obstetric patient. Magnetic resonance images show an epidural blood patch leaking through the intravertebral foramina of young individuals,[8] but in an elderly lady with spinal pathology[9] images show compression of the medulla caused by local anaesthetic (and cerebrospinal fluid). This could have been the pathophysiology behind some of the cases presented in the NAP3.

According to the press release covering NAP3, overall incidence of complications was much lower than previously believed. This good news would have been plausible, considering the possible impact of several studies published in recent years. And indeed, compared with the overall incidences of ~1:1000 after perioperative EB reported by two recent reports,[10 11] the incidences in the NAP3 are lower, even including completely resolved cases.

However, the overall incidence of complications after perioperative EB in NAP3 was almost identical to the incidence found in our study. In NAP3, 26 complications associated with 97 925 perioperative EB (excluding one cardiovascular collapse) and two complications after 16 525 combined spinal–epidural (CSE) allow an incidence of 1:4000. In Sweden, 63 complications in 245 000 perioperative EB (including CSE) account for an incidence of 1:3880.

For the individual patient, there is little, if any, difference in probability of developing a complication according to any one of these above-mentioned incidences. But do

the results of the NAP3 study really support the conclusion that the risks are much lower than perceived? In addition, the verbal description of incidences probably influences future anaesthesiologic practice more than naked numbers. Overoptimistic interpretation of data might therefore retaliate, and that would be a sad way to dissipate the results of this extensive and successful work.

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Editor—We welcome Dr Moen and colleagues' interest in the Third National Audit Project of the Royal College of Anaesthetists (NAP3).[1] It is particularly welcome because they are the authors of a widely quoted study on the same topic.[5] Their letter is long and there is not enough space to address each issue raised in full here. In addition, much of what we might say was published in the full project report to which we would refer them and other readers.[12] We believe that this is appropriate; the article published in the *British Journal of Anaesthesia* stands on its own, but it is primarily a quantitative analysis and précis of a very large audit, and the report (freely available on the website of the Royal College of Anaesthetists)[12] is a more discursive document.

Before addressing their letter in detail, it is perhaps worth commenting that, although the project results received a lot of media interest and considerable international coverage, not a single enquiry from a journalist was related to *perioperative* CNB. Indeed, our efforts to publicize those results (which were included in all press releases) were repeatedly thwarted by journalists, who reported exclusively on the project's relevance to obstetrics. In contrast, all the academic correspondence to date has focused almost entirely on perioperative CNB. This dichotomy of focus is worthy of reflection.

Dr Moen and colleagues raise numerous points, but we will respond only to those relating specifically to the NAP3 results. They emphasize the difference in the risk of complications associated with obstetric and perioperative CNB. We quite agree, and that is why all NAP3 results are presented by clinical indication. Further, in the full report,[12] the complications relating to each clinical indication are discussed in a dedicated chapter, each of which presents the quantitative data for CNB performed for that indication. Differences in outcome according to clinical indication are emphasized in the executive summary of the report and elsewhere. Finally in Appendix 4 of the report, the full results (by indication and type of CNB) are reported. Of note, we also emphasize widely the pitfalls of comparing incidences between such groups without considering case mix and other factors which make such groups dissimilar.

Like Fowler,[13] Moen and colleagues suggest that NAP3 underestimates the incidence of complications because only complications leading to permanent harm (defined as death or persisting deficit at 6 months after CNB) were included. We agree that there will have been lesser complications of CNB that were not notified to NAP3 and we also excluded serious complications from which patients made a full and documented recovery within 6 months. In order to generate meaningful data from a review of remote reports, it was important that NAP3 used a readily defined and clinically meaningful outcome measure. NAP3 therefore did not include neuropraxias (or other injuries) resolving at 6 weeks or 3 months, or indeed 6 months, but only those leading to persisting deficit at 6 months. NAP3 used a 6 month 'cut-off' and included all persisting deficits, a definition of harm which was considered to be clinically relevant to patients and anaesthetists. We accept that not everyone will agree with this judgement. In contrast to Moen and colleagues, Buggy's[14] accompanying editorial suggested that as some injuries may resolve beyond 6 months, NAP3 may have overstated the incidence of complications. NAP3 did not seek lesser or shorter lived complications and we have no idea how many such complications occurred in our cohort. We therefore intentionally did not analyse our results on this basis and we discourage Moen and colleagues' analysis of our data because we believe that it is not based on robust data capture or case analysis. For instance, five of the 28 cases they refer to had almost complete or complete resolution of symptoms even at the time of notification so were, at worst, transient. Further, 10 (including these five) made a documented full recovery within 6 months, and of the 28, only eight were included in the optimistic interpretation of the data.

Moen and colleagues also take issue with the use of *pessimistic* and *optimistic* interpretations of events reviewed by NAP3. This is discussed both in the paper and the full report of the project and all review panel members were in agreement with the decision to report the data in this manner. All also agreed that the pessimistic interpretation was indeed pessimistic. Of note, one of the authors considered that the term *pragmatic* was a more accurate description of the second group, but it was ultimately agreed to use the more cautious term *optimistic*. NAP3 reports all results with both pessimistic and optimistic interpretation, and each with 95% confidence intervals: addressing both clinical and statistical uncertainty. In practical terms, this provides clinicians with the opportunity to discuss the data with each patient in as much detail as is appropriate. Some may choose to present a single figure, some the range of optimistic and pessimistic point estimates. Some anaesthetists may find this confusing, but by presenting our data as fully and openly as possible we enable clinicians to understand the origin and 'provenance' of the data. We leave them to decide which figures they then choose to use in their clinical practice. Whether the patient had a laminectomy or not was not a factor in classifying outcome.

Moen and colleagues compare one of the point estimates of risk in their study with one of the pessimistic point estimates of NAP3. The use of point estimates rather than confidence intervals undermines this comparison and both pessimistic and optimistic incidences should be considered. Of note, many of the groups in their report had considerably smaller denominators than those in NAP3, and the point estimates therefore have wide confidence intervals. This applies particularly to those with small numerators.[15 16] As discussed in both the paper and the full report, Moen and colleagues place much emphasis on the apparently higher risk associated with female orthopaedic (specifically knee replacement) surgery. However, the apparently zero risk (from their figures) in males undergoing hip replacement and the almost 10-fold lower risk in females undergoing hip replacement are rarely commented on. In order for the comparison between the earlier figures and NAP3 to be valid, the two studies must be methodologically very similar: although NAP3 identified denominator data directly and completely, and sought to identify permanent harm associated with CNB of whatever cause, their study used more secondary calculations to determine denominators, and the complications sought were primarily only neurological and appear to have been less clearly defined. For instance, it is not clear whether cases of spinal cord ischaemia or traumatic peripheral nerve injury were included in their study and it is apparent that wrong route errors, cardiovascular collapse, and drug overdose were not.

A further reason to be cautious about comparisons between these studies is that the distribution of complications differs markedly. As an example, in Moen and colleagues' paper almost 40% of complications were caused by meningitis or cauda equina syndrome: these same complications represent close to 7% of those reported to NAP3. Whether such differences are historical or geographical is likely to be impossible to determine.

Finally, we have commented on the results of both Christie and McCabe's[11] and Cameron and colleagues'[10] studies in our response to Dr Grounds,[17 18] and also on the relevance of Wijeysundera and colleagues'[19] study and how it complements the results of NAP3. These are relevant here too and we reiterate our conclusion that relative to previous studies, the results of the NAP3 project can, in the broadest sense, be considered reassuring: even in the perioperative group. It is always difficult to marry population statistics (which NAP3 reports) with individual clinical risk/benefit (as each clinician must for every patient); this remains a daily challenge.

The NAP3 results should not replace previous estimates of risk associated with CNB, but rather refine them. Although NAP3 does not provide a definitive calculation of risk, because of its size and completeness we believe that its estimates are at least as robust as any previously published. It is welcome when a study generates debate and we thank Drs Moen and colleagues for their contribution to this debate, which no doubt will continue within the pages of journals and coffee rooms of anaesthetic departments.

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