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FORUM

Use of the common gas outlet for the administration of supplemental oxygen during Caesarean section under regional anaesthesia*

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Summary

A postal survey investigating the administration of supplemental oxygen to women undergoing Caesarean section under regional anaesthesia was sent to 262 lead consultant obstetric anaesthetists in the UK. Two hundred and fifteen (82%) completed questionnaires were returned. In 139 units (65%) supplemental oxygen was administered routinely to all Caesarean sections under regional techniques, while in 71 (33%), supplemental oxygen was given only if the procedure was an emergency or if there was evidence of fetal or maternal compromise. In 196 units (91%), the common gas outlet was used as the source of supplemental oxygen, with the standard anaesthetic breathing circuit disconnected in 194 (90%) and the vaporisers left on the back bar in 191 (89%). Critical incidents had occurred in 39 (18%) units using the common gas outlet as a source of supplemental oxygen and 63 (30%) had experience of critical incidents with this practice in a non-obstetric setting. We suggest that supplemental oxygen is more safely administered from a separate and dedicated source.

Keywords *Anaesthesia*: obstetric. *Anaesthetic techniques*: regional. *Oxygen*: delivery systems. *Equipment*: breathing systems. *Caesarean section*.

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It is usual for mothers undergoing Caesarean section under regional anaesthesia to receive supplemental oxygen. From our own experience it is often the common gas outlet of the anaesthetic machine that is the source of such oxygen, with the standard anaesthetic breathing circuit disconnected from the anaesthetic machine and replaced by simple tubing and an oxygen mask. It also seems to be usual for the vaporisers to be left in position on the back bar. Following a critical incident in one of our units, we decided to explore practices of supplemental oxygen administration for Caesarean section under regional anaesthesia in obstetric units in the UK. We wanted to ascertain whether it is common practice to use the common gas outlet as a source of supplemental oxygen, with the standard breathing circuit disconnected and the vaporisers left *in situ*. We aimed to establish whether this was a factor leading to critical incidents in other obstetric units. We also wanted to establish whether problems had been encountered with such practices in a non-obstetric setting. Finally, as the value of supplemental oxygen for elective Caesarean sections has recently been questioned [1, 2], we took the opportunity to look into which groups of mothers routinely receive supplemental oxygen.

Methods

After approval from the Obstetric Anaesthetists' Association (OAA), a questionnaire and covering letter were distributed in a single posting to the 262 lead consultants in obstetric anaesthesia in the UK listed on the OAA database. Respondents were asked about departmental, rather than personal, use of supplemental oxygen for Caesarean section under regional anaesthesia in that unit (which cases received it; whether the common gas outlet was used; whether the standard breathing system was disconnected; whether the vaporisers are removed from the back bar; and whether there had been any actual or potential critical incidents associated with this practice). A stamped addressed envelope accompanied each questionnaire to maximise the likelihood of return. All responses were kept anonymous.

Results

Two hundred and fifteen completed questionnaires were returned, representing a response rate of 82%. The majority of units gave supplemental oxygen for all Caesarean sections under regional anaesthesia and of the remaining units, most gave it if the procedure was an emergency or if there was evidence of fetal or maternal compromise (Fig. 1). One hundred and ninety-six respondents (91%) used the common gas outlet as a source of supplemental oxygen, 194 (90%) replied that the oxygen tubing replaced the standard breathing circuit and 191 (89%) used the common gas outlet with the vaporisers left in place on the back bar.

Thirty-nine respondents (18%) had encountered critical incidents using the common gas outlet as a source of supplemental oxygen for Caesarean section under regional anaesthesia. Of these, 14 (7% of respondents) had accidentally given volatile agent and 25 (12% of respondents) had experienced problems with anaesthetic circuits not connected to the common gas outlet when needing to administer a general anaesthetic – 24 of these had encountered inadequate pre-oxygenation of mothers as a result of breathing circuits not connected to the common gas outlet. Sixty-three respondents (30%) reported problems in non-obstetric procedures. Forty-three (20%) had encountered accidental volatile agent administration and 22 (10% of respondents) had had problems with disconnected breathing circuits. Of the 43 respondents who reported accidental volatile agent administration, six commented that the incidents had occurred whilst non-anaesthetic personnel (either surgeons or operating department practitioners) were using the anaesthetic apparatus. Overall, 85 respondents (40%) reported having encountered critical incidents as a result of having used the common gas outlet as the source of supplemental oxygen, taking into account both obstetric and non-obstetric settings.

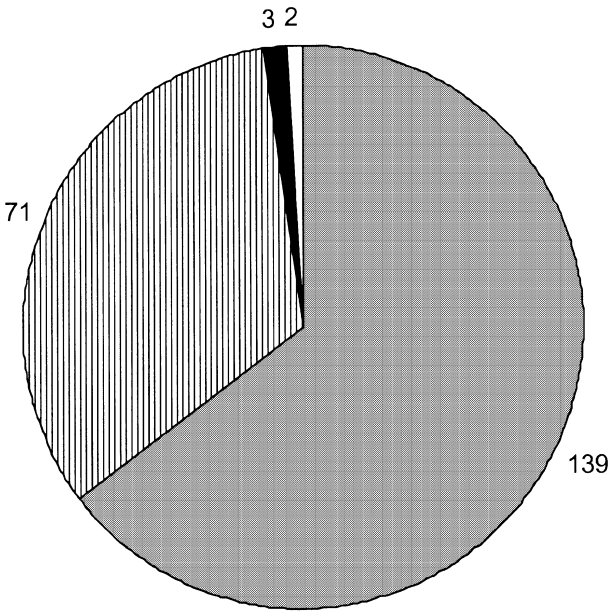

Figure 1 Supplemental oxygen administration practices during Caesarean section under regional anaesthesia amongst obstetric units in the UK ($n = 215$). Values are number of respondents. Grey = all cases given supplemental oxygen; striped = supplemental oxygen only given for emergencies or evidence of fetal/maternal compromise; black = supplemental oxygen not given; white = decision left to individual anaesthetists.

Discussion

We received a brisk and widespread response to our single mailshot. Consultants were asked in the covering letter to complete the questionnaire on behalf of their obstetric unit. The data therefore reflect national practice; to our knowledge this is the first nationwide audit of this topic. There are no published guidelines as to the suitability of the anaesthetic machine as a source of supplemental oxygen for regional procedures, or of the potential hazards involved. A search of the literature revealed little published in this area. Smith, in his case report, highlighted the risks from non-anaesthetic personnel using the anaesthetic machine as a source of supplementary oxygen with vaporisers in position, for an ophthalmology case under regional anaesthesia [3]. Although the risks of certain methods of supplemental oxygen administration have been highlighted before [4], we have found no specific reference to the potential hazards of the use of the common gas outlet of the anaesthetic machine for this purpose.

The critical incident in one of our units occurred during an urgent Caesarean section conducted initially

under a spinal anaesthetic which was converted to a general anaesthetic. The mother had been receiving supplemental oxygen from the common gas outlet of the anaesthetic machine that had been thoroughly checked by the anaesthetist before the case. However, after checking, the circle system had then been unplugged from the common gas outlet by the anaesthetic technician and replaced with oxygen tubing to supply a Hudson mask. When general anaesthesia became necessary, pre-oxygenation via the circle system appeared uneventful and a problem only became apparent when the mother's arterial saturation fell rapidly following a standard rapid sequence induction. Intubation was accomplished easily and the disconnection was detected when the reservoir bag remained flat despite high flow oxygen from the anaesthetic machine. The situation was rectified and the operation proceeded without further event. Our data suggest that this is not an uncommon problem.

Another potential problem of using the common gas outlet with the vaporisers left in position on the back bar is the accidental administration of inhalational agent if the vaporiser is turned on. Our survey demonstrates that this is indeed a source of critical incidents, often when non-anaesthetist personnel used the anaesthetic machine.

Overall, considering both obstetric and non-obstetric settings, 40% of consultants reported having encountered critical incidents with the use of the common gas outlet as a source of supplemental oxygen for procedures conducted under regional anaesthesia. Human error was a major factor in the incident we describe above and was probably a factor in every incident reported to us in our survey. There is no substitute for meticulous equipment checking as recommended by the Association of Anaesthetists [5]. However, our incident occurred despite this and arose from the need to change breathing systems at a time of intense clinical demand. Continuing to use the common gas outlet in this way would thus seem to expose both anaesthetist and patient to an unnecessary risk of a critical incident, and we suggest that a change in practice is necessary. Whilst the risks of accidental volatile administration can be reduced by removing the vaporisers from the back bar of the anaesthetic machine, this currently happens in very few units (2%). Several respondents commented that removal of the vaporisers was impractical (and may introduce new hazards if general anaesthesia is required). Pre-oxygenation with room air (or even a potentially hypoxic gas mixture if a circle system is used) through a disconnected breathing circuit would be prevented by not removing the breathing circuit from the common gas outlet once the anaesthetic machine has been checked. The obvious solution to both problems is to use a separate source of supplemental oxygen, and to leave the common gas outlet exclusively for the use of the anaesthetic breathing system. This practice appears to be uncommon at present (routine in only 9% of units). Many modern anaesthetic machines have a separate oxygen supply for just this purpose, but older machines mostly do not, although they could be modified. Nolan has highlighted the need for system change to reduce errors and adverse events [6]. Living as we do in times of clinical governance and aggressive risk management, is there any justification for continuing to use the common gas outlet as a source of supplemental oxygen for surgical procedures conducted under regional anaesthesia?

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FORUM

Closed loop control of sedation for colonoscopy using the Bispectral Index*

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Summary

Sixteen patients undergoing colonoscopy were sedated with propofol using a closed-loop control system guided by the Bispectral Index (BIS). Propofol administration, via a target-controlled infusion, was controlled by a proportional-integral-differential control algorithm. The median (range) propofol target concentration during closed-loop control was 2.3 (1.7–3.6) $\mu g.ml^{-1}$. The performance characteristics of the system were excellent, with a median absolute performance error of 7 (1–15)%. Patients were drowsy yet rousable, with a median (range) BIS set-point of 80 (75–85). No patient became apnoeic, required airway support or became haemodynamically unstable whilst sedated. Eight patients moaned or moved during colonoscopy and four had recall. Median (range) time to full consciousness was 4 (2–20) min after the end of closed-loop control. Patient and surgeon satisfaction were high. We conclude that BIS may be a suitable control variable for closed-loop control of sedation with propofol.

Keywords *Anaesthetics, intravenous*: propofol. *Anaesthesia, techniques*: closed-loop control. *Measurement, techniques*: Bispectral Index.

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Propofol is a suitable agent for sedation during colonoscopy because of its favourable pharmacokinetic and pharmacodynamic profile [1]. However, excessive sedation may result in respiratory depression and prolonged recovery, and may mask complications, whilst inadequate sedation may decrease patient comfort and prevent an efficient and complete examination. Optimal delivery of propofol may therefore improve patient outcomes.

Closed-loop administration of propofol is one method of improving control of sedation [2]. As drug doses are individualised using a continuously updated measure of anaesthetic depth, control of sedation may be more precise and reliable than open-loop administration. Mortier *et al.* [3] used the Bispectral Index (BIS), a multivariate electroencephalographic (EEG) index [4], to control sedation in patients having surgery under spinal anaesthesia. However, their goal was to render patients unresponsive to all but noxious stimulation. We therefore investigated the effectiveness of a closed-loop system for conscious sedation with propofol, guided by BIS, in patients undergoing colonoscopy.

Methods

The closed-loop system

The details of our closed-loop system have been published in detail previously [5]. Briefly, the control variable is the BIS. The control actuator is a target controlled infusion (TCI) system for propofol, which incorporates the pharmacokinetic parameters used in a

commercially available device (Diprifusor™, AstraZeneca Pharmaceuticals, Macclesfield, UK) [6]. A lap-top computer is used to implement the control algorithm, provide a user interface and control communication with the EEG monitor and TCI system. Custom-made system software was written by Anthony Absalom in Borland Delphi 2 (Inprise Inc., CA, USA).

The TCI system can be operated manually or automatically: in automatic mode, the user enters a target BIS value and minimum target propofol concentration. The closed-loop control program requests an update of the BIS every 5 s, calculates the difference between the set-point and actual BIS value, and uses a proportional-integral-differential (PID) control algorithm to make adjustments to the target propofol concentration every 30 s.

Protocol

With approval from the Institutional Ethics Committees and written informed consent, 16 patients, aged > 18 years and of ASA physical status I–III, scheduled for colonoscopy, were studied. Patients with brain pathology that would compromise EEG monitoring were not studied.

No sedative premedication was given. Oxygen was administered via a Hudson mask. A 22-gauge intravenous cannula was inserted into a forearm vein and hyoscine 20 mg was administered intravenously, to relax the bowel. The EEG was acquired using a BIS sensor (Aspect Medical Systems Inc., MA, USA). After confirming that all impedances were < 5000 Ω, BIS (version 3.4) was calculated, displayed and recorded continuously (A-2000 EEG monitor, Aspect Medical Systems Inc., MA, USA). Arterial pressure, heart rate and oxygen saturation were measured non-invasively every 5 min The Observer Assessment of Alertness and Sedation (OAA/S) rating scale [7] was used to assess sedation during induction and every 5 min during the procedure (Table 1). A modified Aldrete score was used to assess recovery from sedation [8].

Initially, propofol was administered at a target blood concentration of 2 $\mu g.ml^{-1}$. This was manually increased in steps of 0.5 $\mu g.ml^{-1}$ every minute until the sedation target (OAA/S rating of 3) was reached. The BIS value when the sedation target was reached was noted. Closed-loop control of sedation was then initiated using this BIS value as the set-point. Inappropriately light or deep sedation was managed by altering the BIS set-point. The surgeon commenced the procedure when the patient's OAA/S rating was 3. Propofol administration was ceased near the conclusion of the colonoscopic examination and patients were transferred to the recovery room.

Induction time (time to OAA/S = 3), induction dose and total dose of propofol, target propofol concentrations, signs of inadequate sedation (moaning and movement), duration of closed loop control, duration of colonoscopy and recovery times (time to OAA/S = 5 and time to Aldrete score ≥ 8) were noted. During recovery, patients were questioned about their memories of the procedure. Patients and surgeons were asked to rate their satisfaction with sedation on a 5-point scale (1 = poor; 5 = excellent).

Table 1 Observer Assessment of Alertness/Sedation rating scale (OAA/S).

Rating	Sedation level
5	Responds readily to name spoken in normal tone
4	Lethargic response to name spoken in normal tone
3	Responds only if name called loudly or repeatedly
2	Responds only after mild prodding or shaking
1	Does not respond to mild prodding or shaking; only after noxious stimulation
0	Does not respond to noxious stimulation

Data analysis

Data were first tested for normality. Parametric data are presented as mean (SD) and non-parametric data are presented as median (IQR [range]). Performance error (bias), absolute performance error (inaccuracy), wobble (variability) and divergence (time-related trends) of the closed-loop system were calculated using the methods of Varvel *et al.* [9]. Offset was defined as the measured BIS value minus the set-point. The proportions of BIS values within 5%, 10% and 15% of the set-point were also calculated. Pearson correlation was used to assess the relationship between incomplete satisfaction with sedation (rating < 5) and inadequate sedation (moaning or movement). Statistical analyses were performed using Stata 6.0 (Stata Corporation, Texas, USA); $p < 0.05$ was considered statistically significant.

Results

Nine women and seven men, aged 60 (16) years and weighing 72 (11) kg, were studied. The induction time (time to OAA/S = 3) was 5 (2) min; colonoscopy lasted 24 (18–28 [11–54]) min and the duration of closed-loop control of sedation was 19 (17–27 [7–50]) min.

The median OAA/S score was 3 (3–3 [2.5–4]). Nine patients had OAA/S scores ≥ 3 during closed loop control. Seven patients had an OAA/S score of 2 for 25 (24–33 [17–44])% of closed loop control time and an OAA/S score ≥ 3 for the remainder of closed loop control. The set-point was decreased by five BIS units in six patients because of inadequate sedation.

The induction dose of propofol was 100 (32) mg and the total dose was 246 (82) mg. Median propofol target

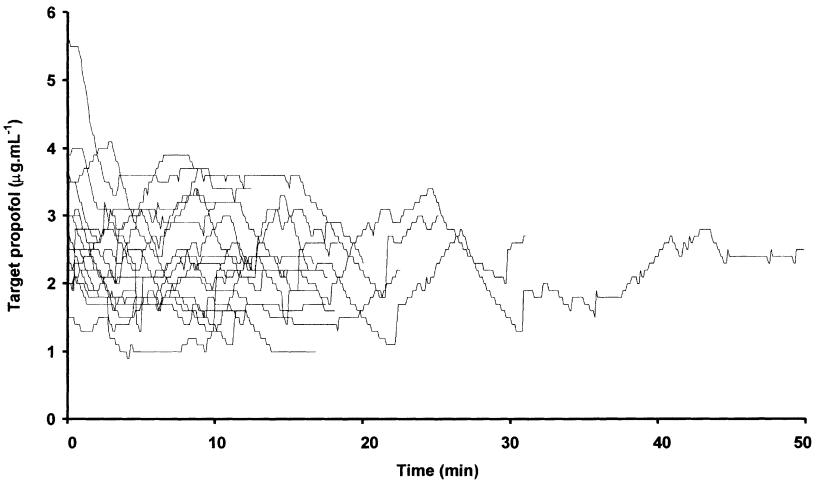

Figure 1 Target propofol blood concentration ($\mu g.ml^{-1}$) during closed-loop control of sedation in 16 patients.

concentrations during closed-loop control were 2.3 (1.9–2.8 [1.7–3.6]) $\mu g.ml^{-1}$ (Fig. 1). The maximum target concentration in any patient was 5.6 $\mu g.ml^{-1}$. This patient required propofol 160 mg to achieve an OAA/S = 3. The minimum was 0.9 $\mu g.ml^{-1}$ in a patient who had an OAA/S = 4 at the time. The performance characteristics of the system are presented in Table 2 and Fig. 2.

No patient became unrousable (OAA/S = 1), apnoeic or required airway support whilst sedated and minimum oxygen saturations were > 95% in all but one patient (93%). Half of the patients moaned or moved at some point during closed-loop control. The maximum decrease in heart rate from control was − 13 (− 18 to − 6 [− 50–0])% and the maximum increase was 0 (0–10 [0–58])%. The maximum decrease in systolic arterial blood pressure from control was − 8 (− 22 to − 5 [− 33–0])% and the maximum increase was 2 (0–21 [0–40])%.

An OAA/S rating of 5 was reached 4 (3–9 [2–20]) min, and an Aldrete score ≥ 8 was reached 4 (3–4 [0–18]) min, after the end of closed-loop control. Three patients recalled changes in position and abdominal compression during their colonoscopy and one remembered pain on injection of propofol. The median patient satisfaction

Table 2 Performance of BIS-guided closed-loop sedation.

Performance Indicator	Value
Setpoint	80 (80–80 [75–85])
Median Bispectral Index; BIS	79 (3)
Median performance error; %	− 1 (4)
Median absolute performance error; %	7 (3–10 [1–15])
Median wobble; %	6 (3–9 [1–14])
Divergence; $BIS.h^{-1}$	0 (− 0.1–0.1 [− 0.8–0.2])
Median offset; BIS	− 1 (3)
BIS values within 5% of setpoint; %	36 (25–67 [8–96])
BIS values within 10% of setpoint; %	81 (50–89 [28–100])
BIS values within 15% of setpoint; %	96 (81–100 [50–100])

BIS = Bispectral Index. Data are presented as mean (standard deviation) for parametric data and median (IQR [range]) for non-parametric data.

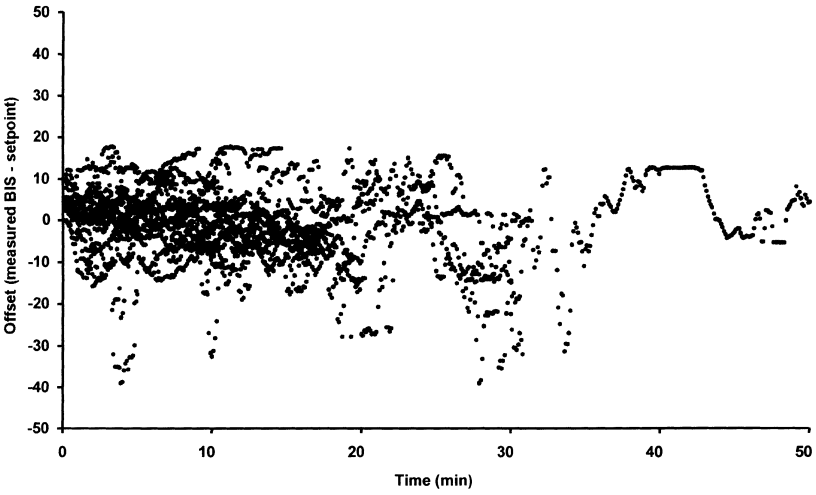

Figure 2 Offset values (measured Bispectral Index [BIS] – setpoint) during closed-loop control of sedation in 16 patients.

score was 5 (5–5 [2–5]) and satisfaction was not correlated with recall ($r = 0.30$; $p = 0.26$). Two patients recorded a satisfaction level of < 5, but only one of these had any recall. Surgeon satisfaction [4 (3.5–5 [2–5])] was significantly correlated with the adequacy of sedation ($r = 0.77$; $p = 0.004$).

Discussion

The choice of control variable is crucial to the success of a closed-loop system [10]. Several derivatives of the EEG have been proposed as suitable control variables for closed-loop control of propofol anaesthesia. For example, the median frequency performed adequately in lightly anaesthetised volunteers who did not undergo surgery [11] and a closed-loop system using the auditory evoked potential index (AEP_{ex}) controlled anaesthesia well in spontaneously breathing patients having surgery [12]. However only BIS has been investigated as a control variable for both general anaesthesia [5, 13, 14] and sedation [3].

BIS was reported to be a suitable control variable for general anaesthesia controlled by a variety of closed-loop algorithms [5, 13, 14]. Our closed-loop control system performed well previously in patients under combined general and regional anaesthesia (median performance error: 2.2 (2.3)%) [5]. Morley *et al.* [13] reported similar performance with their PID algorithm, although closed-loop control offered no clinical advantage over manual control guided by BIS in their study, except in terms of convenience. In contrast, the model-based adaptive algorithm of Struys *et al.* [14] was superior to manual titration of anaesthesia guided by haemodynamic signs (median performance error: -6 (10)% vs. -13 (22)%; $p < 0.05$). The choice of control variable in the manual titration groups in these studies probably explains this difference.

The margin of safety for control of hypnosis is much lower in the conscious sedation range, as noxious stimulation may easily arouse the patient into full consciousness while excessive sedation may result in respiratory depression. In addition, the EEG signal may be harder to measure continuously due to movement artefact [4, 15]. The choice of control variable is therefore especially crucial during sedation.

BIS was investigated as a control variable for sedation in one previous study. Mortier *et al.* [3] used a model-based adaptive algorithm to target a BIS set-point near 64 during regional anaesthesia. Their system appeared to maintain stable BIS values, but no performance parameters were reported. Patients in their study were deeply sedated (OAA/S score = 1). Our study is the first to test a BIS-guided closed-loop system for conscious sedation, without concurrent regional anaesthesia or analgesia to ablate noxious stimulation. The system controlled BIS in the conscious sedation range adequately, demonstrating similar performance characteristics to previous reports [3, 13].

The system was not completely successful in suppressing arousals during colonoscopy, which resulted from difficult passage of the endoscope or abdominal compression. Although our endoscopists were less than completely satisfied with sedation if the patient moved, commentators suggest that, if patients can respond to painful stimulation, colonic perforation may be prevented or detected more readily [16]. Sedation was adequate from the patients' perspective, as few patients recalled any part of their procedure and recall was not correlated with dissatisfaction.

Our goal in this study was to produce 'conscious sedation'; that is, patients who were amnesic and comfortably drowsy, yet responsive to command. No patient was unresponsive to mild tactile stimulation at any time and none required airway support. However, some patients were unresponsive to verbal command for short periods during closed-loop control. The use of closed-loop control therefore does not obviate the need for close observation of the patient by the anaesthetist.

The problem of oscillations in the control variable may be addressed in several ways. Adding an opioid analgesic drug to our protocol may have improved tolerance of noxious stimulation [17], although this may have led to more respiratory depression. The use of a TCI system targeting propofol effect-site concentration, rather than blood concentration, would allow the closed-loop system to increase anaesthetic depth more rapidly and reliably [18]. Finally, the use of an adaptive model-based system would probably improve control of sedation because the control parameters are individualised to each patient [10].

In conclusion, we used a closed-loop system incorporating a proportional-integral-differential algorithm to control BIS to a user-defined value during sedation with propofol for colonoscopy. The system was satisfactory from a performance and clinical perspective.

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FORUM
Patient feedback on the anaesthetist's performance during the pre-operative visit

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Summary

A questionnaire was devised from guidelines published by the Royal College of Anaesthetists and the Association of Anaesthetists of Great Britain and Ireland for the conduct of the pre-operative interview and conduct of anaesthesia. The responses to the questionnaire formed the basis of an accumulative record of patient feedback on individual anaesthetist's performance and used as one component of annual appraisal. The median 'desired answer' and 'overall dissatisfaction' percentages, and the 'desired : undesired answer' ratio for consultants and non-training grade doctors from 835 patients at a large Acute District General Hospital were 92%, 0.6% and 12 : 1, respectively.

Keywords *Data collection:* questionnaire. *Professional patient relations:* physician patient relations. *Patient care:* pre-operative care.

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Doctor patient interaction is an important part of medical practice. This interaction, for the majority of anaesthetists, is a time-limited process initiated at the pre-operative interview. The Royal College of Anaesthetists and the Association of Anaesthetists of Great Britain and Ireland [1] have mandated all anaesthetists to demonstrate satisfactory patient relationships and treatment as demonstrated by objective measures sufficient to meet the requirements set by the General Medical Council for revalidation based on principles outlined in its document Good Medical Practice [2]. Both these bodies have published guidelines and recommendations on important elements for conducting both the pre-operative interview and anaesthetic care [3, 4]. A questionnaire was constructed based on these recommendations to form the basis for obtaining patient feedback for all the anaesthetic members of a large acute District General Hospital. An accumulative record was to be constructed to determine the extent of individual compliance with the guidelines.

Method

A questionnaire was devised with the question source taken from professional guideline publications. These included the Royal College of Anaesthetists fellowship examination curriculum pre-operative interview section [4], the Association of Anaesthetist's guidelines on information and consent for anaesthesia, which identifies the importance of discussion of the procedures associated with anaesthesia, the potential complications and risks [5]. Their joint publication regarding factors important for appraisal was an additional source of questions [1]. The questionnaire was constructed to fit on an A4 page, with invited comment overleaf. It comprised 14 questions, which covered categories such as the anaesthetist's demeanour and conduct, discussion of complications, anaesthetic procedure proposed, postoperative pain relief and a final question asking for an overall opinion of the anaesthetic care given (see Table 1). The local Research

Table 1 Patient Questionnaire.

Anaesthetic Care Survey
Birmingham Heartlands and Solihull Trust Hospitals
Dear,
As we aim to improve and maintain the quality of care we give to our patients, we would appreciate your help in completing this form. You do not have to take part and your care will not be affected if you decline.
Your replies will be treated in confidence and you will not be personally identified to your anaesthetist. After your procedure and when you are able, please complete this form. This will be collected by the anaesthetist who asked you to complete this questionnaire and gave you an explanation of this survey
Thank You.

Date Surgery Speciality Anaesthetist		circle answer
1	Did you feel you had enough time with your anaesthetist before your operation?	Yes/No
2	Did you consider you had sufficient privacy for the interview?	Yes/Not Really/No
3	Did your anaesthetist introduce himself/herself by name?	Yes/No
4	Did you feel comfortable talking to your anaesthetist?	Yes/a little uncomfortable/No
5	Where did you first speak with your anaesthetist?	Ward/Theatre area
6	Did your anaesthetist use medical terms you were unfamiliar with?	Yes/No
7	Were you able to express any concerns relating to the anaesthetic procedure?	Yes/No
8	Did your anaesthetist give you an adequate explanation of the anaesthetic procedure proposed?	Yes/No
9	Did your anaesthetist give you an adequate explanation of the possible anaesthetic problems associated with your specific procedure?	Yes/No
10	Were you able to express any concerns you may have had over these specific problems?	Yes/No
11	Were you able to express any concerns you may have had over pain relief after surgery?	Yes/No
12	Did your anaesthetist ask if you had any questions relating to the surgery proposed?	Yes/No
13	Did you have any problems with your anaesthetic that were not explained to you? If yes please give details overleaf.	Yes/No
14	Generally, were you satisfied overall with the anaesthetic care you received?	Yes it was very good/it was all right/it could have been better.

If it could have been better, or if you have suggestions for any improvements, please help us by giving details overleaf.

Ethical Committee gave approval and advice for the construction and administration of the questionnaire.

A desired answer was indicated by appropriate Yes/No answers for 11 questions and by one of a more qualified choice in three questions. Questions 2 and 4 were considered to be undesirable if any answer other than 'yes' was given. Question 14 was considered undesired if 'it could have been better' was returned.

The questionnaire was distributed to patients undergoing elective surgery as inpatients or day cases. The distribution was co-ordinated by anaesthetic trainees who ensured that the principle anaesthetist for the procedure was identified and the questionnaire given to consenting patients when able to self-complete the questionnaire.

Manpower constraints only allowed for the distribution of questionnaires for short periods every 6 months achieving a representative sample of patients with a minimum 5% of the annual caseload. The survey commenced in September 2000 and was thereafter repeated at 6 monthly intervals.

The analysis of completed questionnaires was used to construct an accumulative record of each anaesthetist's performance in relation to the percentage of *desired answers and* percentage of *overall dissatisfied patients*. The details of reasons for dissatisfaction were also recorded.

Results

Three separate returns have accumulated results for 41 non-training grade anaesthetists and for 54 rotational trainees since September 2000. Inspection of each survey cycle returns demonstrated no significant difference between the results achieved by trainees or non-training staff members. Individual records were available for all rotational trainees but were not entered into the accumulative record. This was confined to consultants and non-training grade anaesthetists and 835 patients have been included to date (see Table 2).

The principle finding was a median *desired answer* percentage of 92% and an *overall dissatisfaction* percentage of 0.6%. The range for consultant staff was from 80% to 96%. The *desired : undesired answer* ratio for individual anaesthetists showed a median value of 11. The range for consultant staff was from 4 : 1 to 27 : 1 with a median of 12 : 1.

Three parents returned *overall dissatisfaction* on behalf of their children. This was attributed to the conduct of induction venepuncture that was considered to have caused unnecessary distress. One adult patient returned *overall dissatisfaction* due to a complication of a local peribulbar block although documenting that this risk had been extensively discussed and accepted before surgery. One adult patient was unhappy with the time given for his pre-operative visit. All questionnaires with more than five undesired answers or written comment were copied to the individual anaesthetist. The patients volunteered many complimentary comments, but these were not recorded in the accumulative record.

Discussion

Doctor patient interaction is especially difficult for anaesthetists because of brevity of time and the lack of opportunity to develop a relationship by repeated contact. The proposed anaesthetic technique has to be mutually agreed with a fully informed patient. The knowledge, attitude, demeanour and behaviour of anaesthetists towards patients are now specifically identified training requirements [6]. A recent Australian study of patient satisfaction after anaesthesia returned a dissatisfaction percentage of 0.9% in over 10 000 patients [7], similar to that identified in our survey. The Australian authors correlated this dissatisfaction with anaesthetic complications such as awareness, acute pain, postoperative nausea and vomiting. Their survey did not attempt to collect data as to the conduct of the anaesthetist or what had been discussed and agreed but concentrated only on procedural detail and outcome as determinants of dissatisfaction.

The latest guidelines form the Department of Health on obtaining consent for anaesthesia re-emphasise the need for mutual agreement and patient specific information and risk explanation [8]. This advice has been expanded to include the provision of advance written information to strengthen subsequent contact with their anaesthetist.

The principle finding from the accumulated record was a median *desired answer* percentage of 92% and an *overall dissatisfaction* percentage of 0.6%. The range for consultant staff was from 80% to 96% and 0% to 8%, respectively, where more than 10 patients had been surveyed for each anaesthetist. An inspection of the averaged *desired : undesired answer* ratio for individual consultant anaesthetists, showed a median value of 12 and a range extending from 4 : 1 to 27 : 1. This highlights the difference between anaesthetists in communicating information, with one consultant achieving 27 desired answers for every one undesired answer in 12 patients, contrasted with one individual who achieved four desired answers for every one undesired answer in 13 patients.

The accumulated records have helped identify a directorate target for desired *answers* of $> 85\%$ and overall dissatisfaction of $< 1\%$. These records have been one component for discussion at the annual appraisal interviews for consultant staff members and non-training grade staff. On the basis of these returns, individual consultants have

Table 2 Patient Feedback Questionnaires September 2000–September 2001.

Consultants	Patients surveyed	Desired answers	Undesired answers	Ratio desired/ undesired answers	% desired answers	Dissatisfied patients
1	13	173	43	4	80%	
2	30	362	61	6	86%	
3	15	194	26	7	88%	1 of 15
4	33	413	53	8	89%	1 of 33
5	12	157	20	8	89%	
6	17	206	25	8	89%	
7	4	50	6	8	89%	1 of 4
8	21	290	28	10	91%	
9	14	187	18	10	91%	
10	30	388	37	10	91%	
11	6	74	7	11	91%	1 of 6
12	28	375	34	11	92%	
13	10	134	12	11	92%	
14	40	504	43	12	92%	
15	39	518	44	12	92%	
16	52	733	62	12	92%	
17	19	255	20	13	93%	
18	25	329	23	14	93%	
19	35	463	32	14	94%	
20	7	87	6	15	94%	
21	34	446	28	16	94%	
22	42	582	36	16	94%	
23	30	388	21	18	95%	
24	27	368	19	19	95%	
25	13	167	8	21	95%	
26	17	232	10	23	96%	
27	4	54	2	27	96%	
28	12	164	6	27	96%	1 of 12
29	*	*				
Consultant Totals/ median value	629			12	92%	5
Clinical Assistants						
1	11	129	14	9	90%	
2	40	548	33	17	94%	
3	20	276	16	17	95%	
Staff Grades						
1	4	44	11	4	80%	
2	25	289	53	5	85%	
3	38	468	60	8	89%	
4	4	49	6	8	89%	
5	9	118	6	20	95%	
6	0					
7	0					
Associate Specialists						
1	23	266	45	6	86%	
2	32	431	33	13	93%	
Non-training grades Totals/median value	206			9	89%	
Totals/Median values	835			11	92%	

identified training needs in communications skills. Furthermore, the identified deficiencies have stimulated an update of our written pre-operative anaesthetic information.

Delivery of any service requires a measure of the quality of that service, and difficulties in the provison of a service need to be identified. Specific patient comment is an essential component of the delivery of an anaesthetic service. To satisfy objective independent scrutiny, such as may be required for appraisal or revalidation, the *Patient Feedback Questionnaire* appears to be a good way of demonstrating the patients' perspective on delivered anaesthesia.

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FORUM

Prediction by computerised tomography of distance from skin to epidural space during thoracic epidural insertion

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Summary

In this single group observational study on 29 patients, we describe a technique that predicts the depth of the epidural space, calculated from the routine pre-operative chest computerised tomography (CT) scan using Pythagorean triangle trigonometry. We also compared the CT-derived depth of the epidural space with the actual depth of needle insertion. The CT-derived and the actual depths of the epidural space were highly correlated ($r = 0.88$, $R^2 = 0.78$, $p < 0.0001$). The mean (95% CI) difference between CT-derived and actual depths was 0.26 (0.03–0.49) cm. Thus, the CT-derived depth tends to be greater than the actual depth by between 0.03 and 0.49 cm. There were no associations between either the CT-derived or the actual depth of the epidural space and age, weight, height or body mass index.

Keywords *Postoperative analgesia*: epidural. *Surgery*: thoracotomy.

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Thoracic epidural analgesia is one of the most effective methods of pain relief for thoracic surgery [1] and it is the only technique in which improvements in surgical outcome have been demonstrated, particularly in high-risk patients [2–4]. However, insertion is not without risk as the spinal cord usually descends to the level of the first lumbar vertebra (L_1). The potential complications of spinal cord damage and lifelong quadriplegia, although relatively rare [5–7], are catastrophic. If the epidural needle length from the skin to the epidural space could be predicted before insertion, then risks associated with thoracic epidural insertion might be reduced.

A number of authors [8–10] have studied the relationship of factors such as gender, body weight, weight-to-height ratio and body mass index (BMI) to the distance from the skin to the epidural space. However, none of

these factors has proved helpful in predicting depth of the epidural space during insertion.

Patients undergoing thoracotomy routinely have pre-operative chest computerised tomography (CT) scans. From Pythagorean triangle trigonometry, hypotenuse length can be calculated when perpendicular distance and sinα are known (Appendix 1). During epidural midline insertion, a CT-derived distance from the skin to the epidural space can be calculated using the perpendicular distance obtained from chest CT films and the angle of needle insertion. The purpose of this study was to compare a CT-derived distance from the skin to epidural space with the actual length of epidural needle inserted during a midline thoracic epidural procedure.

Methods

This was a single group observational study. After obtaining approval from the local research ethics committee and with patient consent, we studied 29 adult ASA II–IV patients undergoing elective thoracic surgery with thoracic epidural planned for peri-operative pain control. Patients with coagulopathy, sepsis, pre-existing neuropathy or who refused thoracic epidural techniques were not studied.

Thoracic epidural insertion and measurement of the actual epidural needle insertion length

Standard monitoring with indirect arterial pressure, ECG, pulse oximetry and end-tidal carbon dioxide was used during induction of anaesthesia with fentanyl 2–3 $\mu g.kg^{-1}$ and propofol 1–3 $mg.kg^{-1}$; either vecuronium 0.1 $mg.kg^{-1}$ or atracurium 0.5 $mg.kg^{-1}$ was administered to provide neuromuscular blockade. Patients' lungs were ventilated manually with oxygen-enriched air plus isoflurane with a facemask. An appropriate double lumen tube was inserted and the position was confirmed using clinical assessment as a routine and using fibreoscopy if necessary.

The patient was then placed in an appropriate lateral decubitus position for thoracic epidural catheter insertion. The tip of the scapula at the level of the eight thoracic vertebral body (T_8) [11] was used to identify the level of the cephalad end of the spinous processes of T_6 to T_9 for insertion. An aseptic technique with a standard epidural pack (Portex) was employed. Using a midline approach, the epidural needle was advanced slowly until loss of resistance to saline or air was observed. The actual needle length (*a*) at this point was marked on the needle and subsequently measured with a ruler. The angle of needle insertion (αi) between the epidural Tuohy needle and the vertebral bodies was marked on a piece of hard sterile paper held on the patient's skin and subsequently measured with a protractor.

Correct placement was confirmed by easy passage of the catheter into the epidural space, observation of a falling fluid meniscus in the epidural catheter and a negative aspiration test [1].

Calculation of the CT-derived distance from the skin to the epidural space

Chest CT films include a unique measuring scale on each image to allow an accurate measurement of lung anatomy. The patient's routine chest CT film was inspected by a thoracic surgeon, who was blinded to the results of the actual needle length, to determine the distance from the skin to the anterior longitudinal ligament at the corresponding level of T_6 to T_9 inter-spinous spaces. The distance on the CT film in the midline was measured using a ruler against the measurement scale, conventionally represented as a 5-cm scale with 1-cm divisions.

The CT-derived depth was calculated using the principle of Pythagorean triangle trigonometry as shown in Appendix 1.

Statistical analysis

The distribution of residuals was tested for normality using the Shapiro Francia W'test statistic [12]. The comparison between the CT-derived distance from the skin to the epidural space and the actual needle length was analysed using the Pearson correlation coefficient for association, using linear regression and goodness-of-fit (adjusted R^2) for prediction and the Bland-Altman plot for agreement [13]. The association between either the CT-derived distance or the actual needle length with age, weight, height or BMI was analysed using multiple linear regression. The data were expressed as mean (SD) with 95% confidence intervals. A value of $p < 0.05$ was considered statistically significant.

Results

All patients had successful thoracic epidural catheter insertion at levels between T_6 and T_9, which provided adequate peri-operative pain relief. The characteristics of the patients and the associations of these parameters with the actual needle length or with the CT-derived distance from the skin to the epidural space is shown in Table 1.

The actual needle length was highly correlated with a CT-derived depth ($r = 0.88$, $p < 0.01$). Approximately 78% of the variation in actual epidural needle lengths in these 29 patients was due to the association with the CT-derived depths from the skin to the epidural space ($R^2 = 0.78$). However, neither the actual needle length

Table 1 The characteristics of the patients and associations with actual needle length and the CT-derived distance from the skin to the epidural space. Mean (SD) or number, $n = 29$.

		Actual needle length	CT-derived distance
F/M	13/16		
Age; years	57.44 (15.55)	$r = 0.05$ ($p = 0.85$)	$r = 0.22$ ($p = 0.87$)
Weight; kg	69.45 (19.23)	$r = 0.04$ ($p = 0.90$)	$r = 0.01$ ($p = 0.98$)
Height; cm	163.76 (9.02)	$r = 0.31$ ($p = 0.27$)	$r = 0.09$ ($p = 0.75$)
BMI; kg.m^{-2}	25.89 (6.27)	$r = 0.13$ ($p = 0.66$)	$r = 0.04$ ($p = 0.89$)
CT-derived distance		$r = 0.88$ ($p < 0.01$)	
		$R^2 = 77.8\%$	

nor the CT-derived distance from the skin to the epidural space was associated with age, weight, height or BMI.

Table 2 demonstrates the mean, SD and 95% confidence intervals (CI) of the CT-derived distance, the actual needle length, the difference between the CT-derived distance and the actual needle length and angulation of the Tuohy needle.

Figure 1 shows the Bland-Altman plot for assessing agreement between the CT-derived distance from the skin to the epidural space and the actual needle length. The mean (95% CI) difference (CT − *A*) was 0.26 (0.03–0.49) cm. Thus a CT-derived depth from the skin to the epidural space tends to give a higher reading by between 0.03 and 0.49 cm. However, the limits of agreement (− 0.96 to 1.48 cm), which are calculated using mean (2 SD), indicate that the actual needle length will be between ≈1 cm longer and 1.5 cm shorter than the CT-derived distance in 95% of these studied patients.

Table 2 The mean, SD and 95% confidence intervals (CI) of the CT-derived distance from the skin to the epidural space, the actual needle length, difference between CT-derived distance and actual needle length (CT − *A*) and angulation of the Tuohy needle, $n = 29$.

	CT-derived depth; cm	Actual needle length; cm	(CT-A); cm	Tuohy needle angulation; °
Mean	6.62	6.37	0.26	44.60
SD	1.37	1.22	0.62	11.31
CI	6.11–7.13	5.91–6.82	0.03–0.49	38.53–50.59

Discussion

The large *R* found in this study ($R^2 = 0.78$) indicates that use of a CT-derived distance from the skin to the epidural space may provide an useful tool for an anaesthetist to predict the actual epidural needle insertion distance prior to insertion. The mean difference (CT − *A*) was 0.26 cm with 95% CI 0.03–0.49 cm. Thus an actual needle length tends to be less than a CT-derived depth from the skin to the epidural space by between 0.03 and 0.49 cm. This finding suggests that a CT-derived depth may be considered as the maximum safe distance from the skin to the anterior longitudinal ligament (the last ligament before the epidural space).

The wide limits of agreement (− 0.96 to 1.48 cm) reflect large individual variability using this CT-derived method in these 29 patients. This individual variability may arise from failure to locate the corresponding epidural space, the inadvertent use of a paramedian approach or imprecision of measurements.

There were some limitations to measuring the distance from the skin to the anterior longitudinal ligament on a CT scan film. The small scale of the films unavoidably contributes to the imprecision of measurements of a CT-derived depth. It would have been possible to minimise this imprecision if the measurements had made at the time of scanning, when the scale is larger and on-screen computerised measurements can be made.

In this study, the predicted needle length from the CT-derived method was not known until an anaesthetist had inserted an epidural needle and the angle (αi) was then measured. This practical problem could be solved if an epidural needle graduated in millimetres, a disposable

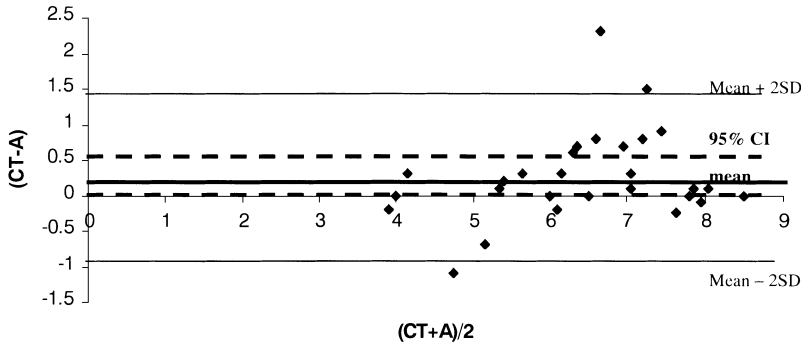

Figure 1 The Bland-Altman plot for assessing agreement between the CT-derived distance from the skin to the epidural space and the actual needle length, the mean difference (CT − *A*, 0.26 cm), 95% CI (0.03–0.49 cm) and the limits of agreement (−0.96 to 1.48 cm).

protractor to measure the insertion angles and a reference table on predicted needle length with commonly encountered measurements over a range of insertion angles were available in epidural packs.

We only recruited patients undergoing thoracotomy to this study, but the technique could be used for any patient requiring an epidural who has a CT scan of the appropriate spinal level.

Conclusions

We have described a technique to predict the depth of needle insertion when performing a midline thoracic epidural approach at a known needle angulation. Used in addition to existing methods of locating the epidural space, this technique may help reduce the potential for spinal cord damage and perhaps make thoracic epidural insertion safer, particularly when the operator is less experienced.

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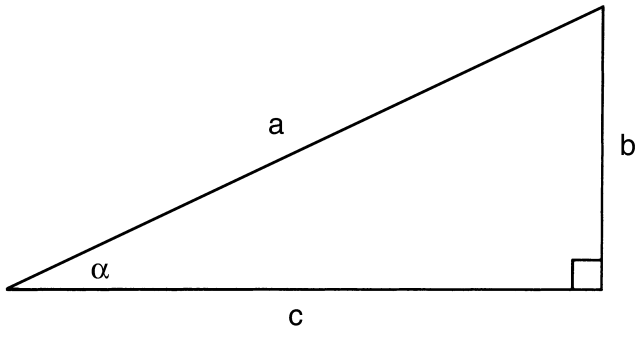
Appendix 1

The CT-derived depth from the skin to the epidural space was calculated using the principle of Pythagorean triangle trigonometry as shown below: $a = \frac{c}{\cos \alpha}$. c was the distance measured on a chest CT film from the skin to the epidural space; αi was the known variables of angle of needle insertion. Therefore, the CT-derived depth from the skin to the epidural space $(a) = \frac{(c)}{\cos \alpha}$ with $\alpha = 90° - \alpha$i.



FORUM

The effect of dexamethasone upon patient-controlled analgesia-related nausea and vomiting

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Summary

Ninety female patients were enrolled in this randomised, double-blind, placebo-controlled study to compare the anti-emetic effect of intravenous dexamethasone 8 mg with saline control in preventing patient-controlled analgesia-related nausea and vomiting following major orthopaedic surgery. The prophylactic administration of dexamethasone 8 mg significantly reduced the overall incidence of patient-controlled analgesia-related nausea and vomiting ($p < 0.001$) and the need for rescue anti-emetics ($p < 0.01$). Furthermore, patients who received dexamethasone showed a higher incidence of complete responses (no vomiting or need for rescue anti-emetic for a 24-h postoperative period) than those who received saline ($p < 0.05$). We conclude that dexamethasone 8 mg may be valuable for preventing patient-controlled analgesia-related nausea and vomiting in women undergoing major orthopaedic surgery.

Keywords *Analgesia*: patient-controlled. *Pain*: postoperative. *Vomiting*: nausea. *Anti-emetics*: dexamethasone.

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Postoperative nausea and vomiting (PONV), which create a very unpleasant experience, are the most undesirable symptoms suffered by patients after surgery [1]. Surgical patients reported the fear of suffering PONV more often than the fear of postoperative pain [2]. Thus, prevention and treatment of PONV is always an important responsibility for the anaesthesia care provider.

Patient-controlled analgesia (PCA) with parenteral opioids has gained widespread acceptance in treating postoperative pain. Their use, however, is associated with a high incidence of nausea and vomiting. An early report stated that as many as 83% of female orthopaedic patients experienced nausea and vomiting after surgery [3]. Other investigators have shown that nearly 80% of patients experienced PONV associated with the use of PCA morphine following major orthopaedic surgery [4, 5].

Dexamethasone has been reported to be an effective anti-emetic in patients undergoing chemotherapy [6–10]. It was also found to be effective in reducing the occurrence of PONV in patients recovering from general anaesthesia [11–18]. Dexamethasone 8 mg has also been shown to be valuable for preventing epidural morphine-related nausea and vomiting [19]. However, its efficacy as a prophylactic anti-emetic in patients receiving postoperative PCA opioids has not been evaluated to date. This study was undertaken to investigate the efficacy of dexamethasone 8 mg i.v. for prevention of PONV in women who received PCA morphine for postoperative pain management following major orthopaedic surgery.

Methods

Following institutional approval and the written informed consent of the patients, 90 female patients (ASA I or II) aged 28–69 years, scheduled for major orthopaedic procedures, participated in this randomised, double-blind, placebo-controlled study. The procedures performed were corrective spinal surgery or prosthetic replacement of hips and knees. Patients with a history of gastrointestinal, liver or renal diseases, those who received any

anti-emetic medication in the previous 24 h before surgery or complained of pre-operative nausea or vomiting were not studied. Those patients who were obese (body mass index > 30 kg.m^{-2}), smoked five or more cigarettes per day, or suffered from a difficult intubation during induction of anaesthesia were also ineligible for the study. Prior to surgery, patients were taught how to use the Abbott PCA pump (Pain Management Provider, Abbott, USA) and were informed that they could request rescue anti-emetic if needed.

Monitoring included continuous ECG, non-invasive or invasive blood pressure, capnography and pulse oximeter. Patients were randomly allocated by means of computer-generated numbers to one of two treatment regimens: dexamethasone 8 mg or saline control ($n = 45$ in each group). The study medications (2 ml), prepared by personnel blinded to the study, were administered intravenously immediately before induction of anaesthesia.

The anaesthetic regimens were uniform in all patients. Anaesthesia was induced with i.v. glycopyrrolate 0.2 mg, fentanyl 2 μg.kg^{-1} and thiopentone 5 mg.kg^{-1}. Tracheal intubation was facilitated by rocuronium 0.8 mg.kg^{-1}. After tracheal intubation, anaesthesia was maintained with nitrous oxide 50% and sevoflurane 2–4% in oxygen. Ventilation was controlled mechanically and was adjusted to keep end-tidal carbon dioxide between 4 and 5.3 kPa throughout surgery. Neuromuscular blocking drugs were used as required. All patients received ketorolac given intravenously 30 mg, ≈ 30 min before the end of surgery. Upon completion of surgery, nitrous oxide was turned off a few minutes before the discontinuation of sevoflurane. Glycopyrrolate 0.6 mg and neostigmine 3 mg given intravenously were administered for reversal of residual neuromuscular block, and the trachea was extubated. No opioid drugs were administered during the operation. Oesophageal temperature was monitored and maintained at 36–38 °C throughout surgery.

Postoperatively, analgesia was provided by a PCA pump set to deliver a 1-ml bolus of morphine 1 mg.ml^{-1} with a 5-min lockout interval for 3 days. No background infusion was used. For the first 24 h after anaesthesia, the presence or absence of nausea and vomiting was recorded by a trained nurse anaesthetist blinded to which treatment the patients had received. Episodes of PONV were identified by direct enquiry or by subjective complaint of the patient every 6 h except during sleep. In this study, a retching event was defined as the spasmodic, rhythmic contraction of the respiratory muscles without the expulsion of gastric contents, and was considered as equivalent to vomiting. A totally effective anti-emetic response, coded as a 'complete' response, was defined as no vomiting and no administration of rescue anti-emetic medication for the duration of PCA usage.

The incidences of PONV and amount of morphine used within the total 24 h observation period were recorded. Average postoperative pain intensity was assessed by the patients themselves using an 11-point scale, 0 representing no pain and 10 the worst pain imaginable. Episodes of vomiting, use of rescue anti-emetics and complete responses were evaluated. A single vomiting episode was recorded even if several vomiting events occurred in rapid sequence within 1 min. Separate episodes of vomiting were considered if the interval between bouts of emesis exceeded 1 min [20]. Vomiting was considered severe if episodes occurred more than four times within a 24-h observation period [16]. Metoclopramide 10 mg i.m. was given as rescue treatment if it was needed or requested by the patients.

Parametric data were analysed with an unpaired *t*-test. The incidence of PONV at various time intervals, severity of vomiting, requirements for rescue anti-emetics and complete responses were evaluated by using Fisher's exact test. The pain scores were analysed by using the Mann–Whitney *U*-test. A p-value < 0.05 was considered significant. Data are expressed as mean values with standard deviations (SD) or number and percentage. We regarded a 30% difference in the total incidence of PONV between groups as clinically significant, given a SD of 40%. The α error was set at 0.05 and the β error at 0.10. Analysis showed that 37 patients per treatment group would be sufficient [19, 21].

Results

The groups were comparable with respect to patient characteristics, duration of anaesthesia and surgery type (Table 1). The 24-h postoperative morphine consumption and severity of pain (pain score) were similar between groups. Of the 90 patients enrolled in the study, three were excluded from analysis: one required a further

Table 1 Patient data, surgery type, 24 h morphine consumption and pain score. Mean (range).

	Dexamethasone ($n = 43$)	Saline ($n = 44$)
Age; years	42.3 (28–67)	44.6 (32–69)
Weight; kg	65 (52–90)	67 (54–84)
Surgery type		
Total hip replacement	13	16
Total knee replacement	16	15
Corrective spinal surgery	14	13
Duration of anaesthesia; min	131 (89–223)	127 (92–215)
24-h morphine consumption; mg	43 (25–77)	40 (26–72)
24-h pain score	3 (1–6)	3 (1–7)

No significant differences between groups.

operation 24 h after spinal surgery because of continuous postoperative bleeding and two were not followed up adequately. Therefore, 87 recruited patients completed the study.

The data relating to postoperative nausea and vomiting are presented in Table 2. During the first 6-h postoperative period, the actual incidence of nausea and vomiting was lower in the dexamethasone group than in the saline group, although this did not reach statistical significance. During the observational periods of 6–12 h, 12–24 h and the whole 0–24 h, significantly fewer patients in the dexamethasone group reported nausea and vomiting compared with the saline control group ($p < 0.05$; 0–24 h, $p < 0.001$).

The evaluation of vomiting episodes, need for rescue anti-emetics, and complete responses during the first 24 h postoperatively are shown in Table 3. Patients in the dexamethasone group showed a significantly lower incidence of severe vomiting (more than four times during a 24-h period; $p < 0.05$), less need for rescue anti-emetics ($p < 0.01$) and a higher rate of complete responses ($p < 0.05$) than those in the saline group.

No patient reported delay in healing or increased wound infection accompanying dexamethasone usage during their stay in hospital. Other side-effects of dexamethasone, such as euphoria, depression or peptic ulcer perforation were not found in this study.

Table 2 Incidence of nausea and vomiting during the first 24 h postoperatively, *n* (%).

	Dexamethasone (*n* = 43)	Saline (*n* = 44)	p
0–6 h postoperatively			
Nausea only	3 (7)	6 (14)	
Vomiting	2 (5)	6 (14)	
Total	5 (12)	12 (28)	
6–12 h postoperatively			
Nausea only	1 (2)	5 (11)	
Vomiting	1 (2)	4 (9)	
Total	2 (4)	9 (20)	< 0.05
12–24 h postoperatively			
Nausea only	1 (2)	3 (7)	
Vomiting	0 (0)	3 (7)	
Total	1 (2)	6 (14)	< 0.05
0–24 h postoperatively			
Nausea only	5 (12)	14 (32)	< 0.05
Vomiting	3 (7)	13 (30)	< 0.05
Total	8 (19)	27 (61)	< 0.001

Table 3 Vomiting episodes, need for rescue anti-emetics, and complete responses during the first 24 h postoperatively, *n* (%).

	Dexamethasone (*n* = 43)	Saline (*n* = 44)	p
Vomiting episodes			
0–4 times	2 (5)	3 (7)	
> 4 times	1 (2)	10 (23)	< 0.05
Rescue anti-emetics	6 (14)	22 (50)	< 0.01
Complete responses	37 (86)	22 (50)	< 0.05

Discussion

PCA has been used extensively as an effective method to control postoperative pain. Unfortunately, opioid administration by PCA is associated with a high incidence of PONV. A quantitative systemic review reported that the incidence of PONV with PCA-morphine was ≈50% [22]. In our study, 61% of patients in the saline control group reported nausea and/or vomiting during the first 24 h after surgery. After receiving dexamethasone during induction, the total incidence of PONV decreased significantly from 61 to 19%.

The first clinical trial to suggest that dexamethasone may prevent PONV was published in 1993 [23]. Subsequent studies indicated that dexamethasone may reduce the occurrence of PONV in women undergoing major gynaecological surgery [11, 15], ambulatory laparoscopic surgery [24], thyroidectomy [14] and in paediatric patients undergoing adenoidectomy and tonsillectomy [25, 26]. Work has shown that dexamethasone 8 mg given intravenously also reduces epidural morphine-related nausea and vomiting [19]. Hence, it may be effective in the prevention of PCA-related PONV, and this has been confirmed by our study.

The onset time of dexamethasone's anti-emetic effect is ≈2 h [15], and the late (i.e. up to 24 h) efficacy seems to be more pronounced [15, 17]. A previous study stated that most patients receiving PCA-morphine postoperatively vomited in the first 12–24 h [27]. Thus, dexamethasone was administered at the induction of anaesthesia in this study and the data were collected in the first 24 h postoperatively. The results of our study demonstrated that dexamethasone could not only lower the incidence of PONV ($p < 0.001$), but also reduce the severity of vomiting (greater than four times; $p < 0.05$). In addition, patients in the dexamethasone group showed a significantly higher rate of complete anti-emetic response ($p < 0.05$) and requested fewer rescue anti-emetics ($p < 0.01$) than those in the saline group. These results demonstrated that dexamethasone is effective in the prevention of PCA morphine-related PONV.

Although the minimum effective dose of dexamethasone for preventing postoperative emesis in patients undergoing major gynaecological surgery was suggested

to be 2.5 mg [28], a single 8–10 mg dose of dexamethasone was used most frequently [17, 19, 24]. Although it may not be an optimal dose, we found that 8 mg of dexamethasone was able to significantly lower the incidence of PCA-related PONV. Whether a higher dose will increase efficacy without increasing the risk of adverse effects requires further study.

In one trial in adults undergoing extraction of third molars, significantly less intense pain was reported with dexamethasone than placebo [23]. However, for patients undergoing major surgery, the analgesic effect of dexamethasone is only minimal and unsatisfactory [28]. We found that dexamethasone 8 mg did not influence the intensity of surgical pain or enhance the efficacy of PCA morphine. In our study, both morphine consumption and the severity of pain (pain score) were similar between the dexamethasone and the saline control groups.

Both droperidol and ondansetron have been reported to prevent PCA-related PONV [4, 5, 29–31]. However, ondansetron has been criticised because of its high cost (£16.16 for 4 mg) [32, 33], and its efficacy was reported to be no greater than that of droperidol [32]. Droperidol has been proved to be effective when mixed with morphine PCA [22], the optimal dose of droperidol in adults being 0.1 mg per mg of morphine [29]. The cost of 2.5 mg (1 ml) droperidol is £0.30; thus 2 days' infusion with PCA morphine will amount to ≈£0.81–1.62, which is comparable with dexamethasone (£1.82 for 8 mg). However, droperidol may cause excessive drowsiness [34–37]. In our study, no discernible adverse effects accompanying dexamethasone administration were observed. In other studies, adverse effects were rarely reported in patients who received a single dose of dexamethasone for anti-emetic treatment [11–19]. Hence, this study demonstrated clearly that dexamethasone is not only cost-effective, but safe and easy to use for preventing PCA-related PONV.

In conclusion, our study demonstrated that prophylactic therapy with intravenous administration of dexamethasone 8 mg before induction of anaesthesia may be valuable for preventing PCA morphine-related nausea and vomiting in women undergoing major orthopaedic surgery. The optimal dose of dexamethasone needs to be identified in the future.

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