Anesthesiology 2005; 103:126–9

A Comparative Study of Sequential Epidural Bolus Technique and Continuous Epidural Infusion

Kenichi Ueda, M.D., Wasa Ueda, M.D., Ph.D.,† Masanobu Manabe, M.D., Ph.D.‡*

Background: **In this randomized, double-blind study, the authors compared the effectiveness of a sequential epidural bolus (SEB) technique *versus* a standard continuous epidural infusion (CEI) technique of local anesthetic delivery. Both techniques used the same hourly dose of local anesthetic.**

Methods: **Sixteen gynecologic patients undergoing abdominal surgery received postoperative epidural analgesia using 0.75% ropivacaine at a dose of 22.5 mg (3 ml) per hour. Patients were randomly assigned to one of two groups. In the SEB group (n = 8), patients received one third of the hourly dose every 20 min as a bolus. In the CEI group (n = 8), the hourly dose was administered as a continuous infusion. Analgesia was assessed by rest pain scored by a visual analog scale and pinprick to determine the number of separately blocked spinal segments on each side of the body. Doses of rescue medication for pain were also recorded.**

Results: **The median number of blocked spinal segments was 19.5 (range, 18–24) in the SEB group and 11.5 (range, 10–18) in the CEI group ($P < 0.001$). The median difference in the number of blocked segments between the right and left sides was 0 (range, 0–1) in the SEB group and 2 (range, 0–6) in the CEI group ($P < 0.04$). No patients in the SEB group but one patient in the CEI group required rescue medication for pain. The visual analog scale pain score was 0 in both groups except for one patient in the CEI group during the study period.**

Conclusion: **The SEB technique with ropivacaine provides superior epidural block compared with an identical hourly dose administered as a continuous infusion.**

CONTINUOUS epidural analgesia now plays an important role in postoperative pain control.[1] In the standard continuous epidural infusion technique (CEI), the initial dose establishes the requisite extent of analgesia, and then continuous infusion preserves it. Over time, however, some patients experience diminution of analgesia, characterized by a reduction in the number of blocked spinal segments and development of unequal right and left blockade. In such cases, additional top-up doses are necessary. The development of patient-controlled epidural analgesia (PCEA) permitted patients to superimpose a limited volume of bolus dosing on continuous infusion. PCEA was first applied to obstetrics[2] and was then found to be effective in postoperative pain control that requires a steady level of analgesia.[3,4]

Interestingly, patients with PCEA required less local anesthetic than did patients with continuous epidural infusion (CEI) to achieve a similar quality of epidural analgesia.[5] Further, Sia and Chong[6] found that PCEA could provide satisfactory epidural analgesia even when the background infusion was eliminated. These findings caused us to hypothesize that an intermittent bolus administration with regular intervals independent of patient demand could be superior to CEI for producing epidural sensory block with better quality. To test this new epidural delivery mode, we provided postoperative epidural analgesia by two different techniques, using identical hourly doses of local anesthetic. One group of patients received the standard CEI technique. The other group received a sequential epidural bolus technique (SEB) in which one third of the hourly dose was administered every 20 min.

Materials and Methods

The study protocol was approved by the Ethics Committee of the Kochi Medical School (Kochi, Japan) and written informed consent was obtained from each patient. The study group consisted of 16 gynecologic patients with American Society of Anesthesiologists physical status I or II who were scheduled to undergo lower abdominal surgery. None of the patients had previous experience with epidural analgesia.

All patients received standardized anesthetic care by the same anesthesiologist for the surgery. Oral diazepam, 10 mg, was administered 1 h before surgery. The epidural catheter (18 gauge; Portex, Kent, United Kingdom) was placed before induction of anesthesia, with the patient in the right lateral decubitus position, at the T11–T12 or T12–L1 spinal interspace using the paramedian approach. General anesthesia included mask induction with sevoflurane, tracheal intubation, and maintenance with 1.0% end-tidal concentration of isoflurane in oxygen. Muscle relaxation was facilitated with vecuronium. No opioids were administered. After induction of general anesthesia, an initial epidural dose of 8 ml lidocaine, 2%, with 1:200,000 epinephrine was administered. Thereafter, 1 ml lidocaine, 2%, with 1:200,000 epinephrine was given as a bolus every 10 min until the end of the surgery. If a patient showed any reaction to the surgical maneuvers that required more than 1.2% end-tidal concentration of isoflurane to control, we eliminated the case from the study because of failed epidural block.

At the end of surgery, patients were given either SEB or CEI according to a computerized random-number generator. Both groups received 0.75% ropivacaine at a dose of 3 ml/h. In the SEB group (n = 8), ropivacaine was

* Assistant Professor, ‡ Professor, Department of Anesthesia, † Professor, Department of Perioperative Care and Medicine, Kochi Medical School.

Received from the Department of Anesthesia, Kochi Medical School, Kochi, Japan. Submitted for publication October 4, 2004. Accepted for publication February 28, 2005. Support was provided solely from institutional and/or departmental sources.

Address reprint requests to Dr. Ueda: Department of Anesthesiology, Kochi Medical School, Nankoku, Kochi, Japan 783-8505. Address electronic mail to: uedak@gf6.so-net.ne.jp.

given as a sequential epidural bolus of 1 ml every 20 min. In the CEI group (n = 8), ropivacaine was given as a continuous epidural infusion. Patients were blinded to the drug administration technique. On arriving at the postanesthesia care unit, patients were asked to rate their pain experience on a visual analog scale (VAS). Only rest pain was assessed by nurses who were not aware of this study. The patients stayed in the postanesthesia care unit for 3 h to confirm that the pain control was adequate. In the ward, the patients were allowed to take diclofenac suppositories as rescue medication from an independent nurse.

An independent nurse in the ward assessed vital signs and rest pain score by VAS every 4 h. If a patient experienced hypotension, bradycardia, or bradypnea, epidural infusion was discontinued and the acute pain service team was called for assessment. Hypotension was defined as a systolic blood pressure of less than 90 mmHg, bradycardia was defined as a heart rate of less than 50 beats/min, and bradypnea was defined as a respiratory rate of less than 10 breaths/min.

Anesthesiologists who were unaware of the infusion mode visited the patients after the 15 h of ropivacaine infusion. Using a dermatome chart,[7] the extent of analgesia was judged by the number of blocked spinal segments as determined by the pinprick method.

To produce the SEB mode, we modified the program of the standard infusion pump (SP-80RS; Nipro, Osaka, Japan) so that the pump divided the hourly dose into three parts and infused each every 20 min as a bolus (bolus rate of 500 ml/h).

Statistics

A pilot study with 12 patients showed the number of blocked spinal nerve segments to be 21 ± 3 (mean ± SD) in the SEB group and 13 ± 3 in the CEI group. The sample size to give a power of 0.8 with an α of 0.05 was 4 when the expected difference was 8 ± 3. The difference in the number of blocked segments between the right and left sides was 0 ± 0 in the SEB group and 3 ± 2 in the CEI group. The sample size to give a power of 0.8 with an α of 0.05 was 7 when the expected difference was 2 ± 1. Therefore, we decided to use a sample size of 16. The measured data were rejected by normality test, so we compared the two groups by Mann–Whitney rank sum test. Statistical analysis with SigmaStat 3.0 (SPSS Inc., Chicago, IL) yielded a significant probability value of less than 0.05. Continuous data are expressed as medians, with the ranges given in parentheses.

Results

Table 1 shows the demographic data of the patients studied. There was no statistical difference in the physical status between the two groups. Surgical epidural block was successful in all patients. No patient in either group had hypotension, bradycardia, or bradypnea during the study.

Table 1. Demographic Data of the Patients Studied

	SEB Group	CEI Group
n	8	8
Age, yr	33.5 (21–48)	33.5 (20–50)
Height, cm	154 (150–159)	156 (150–162)
Body weight, kg	54 (45–68)	53.5 (48–65)
ASA PS, I/II	7/1	7/1

Values are presented as mean or n, with range in parentheses.
ASA PS = American Society of Anesthesiologists physical status.

Figure 1 shows the extent of sensory blockade obtained after the 15 h of epidural infusion in the study. SEB produced a larger band of sensory blockade. The median number of blocked spinal nerve segments in the SEB group was 19.5 (range, 18–24), and that in the CEI group was 11.5 (range, 10–18) ($P < 0.001$). SEB also significantly improved equal right and left distribution of sensory blockade. The median difference in the number of blocked spinal segments between the right and left sides, expressed by spinal nerve segment, in the SEB group was 0 (range, 0–1), and that in the CEI group was 2 (range, 0–6) ($P < 0.04$).

One patient in the CEI group required rescue medication for left lower abdominal pain. In this patient, there was a significant difference between the right and left side analgesia, with segments T8–L2 blocked on the

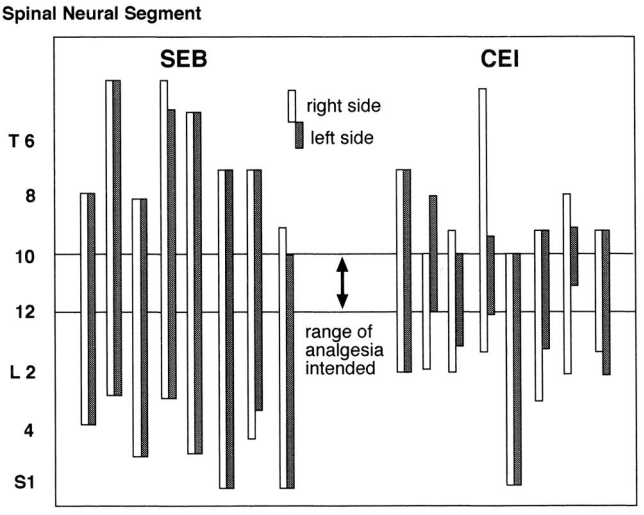

Fig. 1. Extent of sensory blockade after 15 h of epidural infusion. In the sequential epidural bolus (SEB) group (n = 8), 0.75% ropivacaine was given as a sequential epidural bolus of 1 ml every 20 min. In the continuous epidural infusion (CEI) group (n = 8), 0.75% ropivacaine was given as a continuous epidural infusion. The median number of blocked spinal segments was 19.5 (range, 18–24) in the SEB group and 11.5 (range, 10–18) in the CEI group ($P < 0.001$). The median difference in the number of blocked segments between the right and left sides was 0 (range, 0–1) in the SEB group and 2 (range, 0–6) in the CEI group ($P < 0.04$).

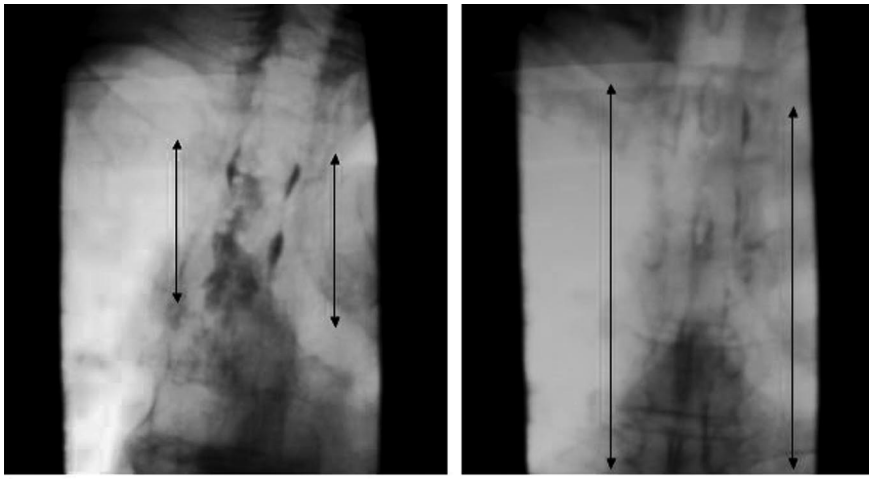

Fig. 2. Spread of contrast medium after injection of 1 ml iotrolan, 240 mg I/ml. Epidurograms *A* and *B* were taken from different patients to locate the epidural catheters, which were placed for chronic pain management. The length of the arrow represents right- or left-sided spread of contrast medium. (Courtesy of Masataka Yokoyama, M.D., Department of Anesthesiology, School of Medicine, Okayama University, Okayama, Japan.)

right side but only T9–T11 on the left side. Accordingly, the pain score at rest by VAS was 0 in both groups, except for one patient in the CEI group who scored 3 as the maximum VAS score during the study.

Discussion

In this study, local anesthetic administered as a sequential epidural bolus (SEB) provided greater longitudinal extension of sensory blockade than continuous epidural infusion (CEI). The SEB technique also improved equal right and left distribution of sensory blockade compared with CEI. We propose some possible explanations.

First, the bolus technique may have a different mode of spread through the epidural space as compared with continuous infusion. It is known that some of the epidural local anesthetic is captured by perineural tissue or removed by blood vessels, making it unavailable for nerve block.[8] A bolus of local anesthetic likely spreads further longitudinally and bilaterally before such capture occurs than does continuous infusion.

It seems unlikely that only a 1-ml bolus of local anesthetic would make such a significant difference as compared with continuous infusion. Nonetheless, 1 ml contrast medium (iotrolan, 240 mg I/ml) when given as a bolus can clearly appreciate an extended area in the epidural space (fig. 2). This is impossible by continuous infusion of the medium. Yokoyama *et al.*[9] showed that the behavior of the local anesthetic and contrast medium inside the epidural space were well correlated. Therefore, bolus dosing has the potential to increase the spread of local anesthetic in the epidural space, and a bolus as small as 1 ml, as used in the current study, might have contributed to the success of SEB.

Second, proper timing of epidural dosing is key to maintain effective analgesia. If diminution of the epidural blockade occurs, sensory neural input to the spinal cord has been shown to accelerate the decline of the block.[10] If this occurs, a larger dose of local anesthetic is required to restore analgesia. If instead the same dose of anesthetic is used before decay of analgesia, the extent of analgesia may increase.[11] In the current SEB, the bolus administration might have occurred at regular intervals before decay of sensory neural block, thereby increasing the number of sensory-blocked spinal segments.

Ropivacaine, 0.75%, produced profound neural block sufficient to control pain without the help of opioids in the current study. Epidural analgesia has commonly been induced with local anesthetic combined with opioids to increase the quality of analgesia. Adverse effects of opioids, however, have the potential to cause complications.[12] To avoid such adverse effects and also to clearly define the range of sensory neural block, we performed epidural block exclusively by local anesthetic. The concentration was decided according to the recommendation by Sakura *et al.*[13]; concentration determines the intensity of sensory block such that a high concentration and a small volume, rather than a low concentration and a high volume, are suitable when profound neural blockade is required. The volume given to the current patients was to achieve sufficient analgesia with CEI and thereby caused no difference in VAS pain score between the SEB and CEI groups. Because the range of blocked segments was so extended with SEB, it may be possible to reduce the dose of the anesthetic in SEB. Further studies are needed to establish the optimal timing, concentration, and volume of anesthetic for SEB in various conditions.

There are limitations to our study design. First, we evaluated the epidural-blocked segments at only a single data point (15 h). We did not study a longer duration of infusion. This may have been insufficient to ascertain the effects of SEB. Secondary, the lidocaine used for surgical anesthesia could have affected our results. We believe this is unlikely because effective surgical analgesia by 2%

lidocaine with epinephrine lasts for 2–3 h at the most.[14] After 15 h, the residual effect of lidocaine is negligible.

Another issue is whether SEB is economical. SEB requires a special infusion pump. To produce the SEB mode, we modified the operating program of a computer-controlled syringe pump for this study. Multipurpose infusion pumps equipped with various infusion modes currently available allow SEB in clinical practice. Such pumps are more expensive than pneumatic infusion pumps. However, an electrical pump uses a disposable plastic reservoir with tubing, which is less expensive and, as a medical waste product, less bulky than a disposable pneumatic infuser. As a whole, the expense associated with the infusion pump may not be a drawback of SEB.

SEB would have the potential to replace CEI in various situations. SEB can be applied to epidural anesthesia during surgery. Also, it can be combined with PCEA. Still, the possibility of local anesthetic overdose by programmed dose administration necessitates careful selection of dose and interval and continued assessment by the anesthesiologist.

In conclusion, SEB improved the quality of sensory blockade as compared with continuous epidural block in this study. This infusion mode has the potential to increase the extent of sensory blockade as well as to decrease unilateral blockade, thereby improving the reliability of epidural analgesia in postsurgical pain control.

The authors thank Masataka Yokoyama, M.D. (Associate Professor of Anesthesiology, Okayama University School of Medicine, Okayama, Japan), for his help in providing epidurographic pictures. The authors also thank William Hammonds, M.D. (Professor), and Alan Ross, M.D. (Associate Professor, Department of Anesthesia, University of Iowa Hospitals and Clinics, Iowa City, Iowa), for helpful comments in the preparation of the manuscript.

References

1. Block BM, Lieu SS, Rowlingson AJ, Cowan AR, Cowan Jr, JA Wu CL: Efficacy of postoperative epidural analgesia. JAMA 2003; 290:2455–63

2. Gambling DR, Yu P, Cole C, McMorland GH, Palmer L: A comparative study of patient controlled epidural analgesia (PCEA) and continuous infusion epidural analgesia (CIEA) during labour. Can J Anesth 1988; 35:249–54

3. Silvasti M, Pitkaenen M: Patient-controlled epidural analgesia versus continuous epidural analgesia after total knee arthroplasty. Acta Anaesthesiol Scand 2001; 45:471–6

4. Standl T, Burmeister M-A, Ohnesorge H, Wilhelm S, Striepke M, Gottschalk A, Horn E-P, Esch JS: Patient-controlled epidural analgesia reduces analgesic requirements compared to continuous epidural infusion after major abdominal surgery. Can J Anesth 2003; 50:258–64

5. Antok E, Bordet F, Duflo F, Lansiaux S, Combet S, Taylor P, Pouyau A, Paturel B, James R, Allaouchiche B, Chassard D: Patient-controlled epidural analgesia versus continuous epidural infusion with ropivacaine for postoperative analgesia in children. Anesth Analg 2003; 97:1608–11

6. Sia AT, Chong JL: Epidural 0.2% ropivacaine for labour analgesia: Parturient-controlled or continuous infusion? Anesth Intensive Care 1999; 27:154–7

7. Barash PG, Cullen BF, Stoelting RK: Clinical Anesthesia, 4th edition. Philadelphia, JB Lippincott, 2001, p 692

8. Bromage PR: Mechanism of action of extradural analgesia. Br J Anesth 1975; 47:199–212

9. Yokoyama M, Hanazaki M, Fujii H, Mizobuchi S, Nakatsuka H, Takahashi T, Matsumi M, Takeuchi M, Morita K: Correlation between the distribution of contrast medium and the extent of blockade during epidural anesthesia. ANESTHESIOLOGY 2004; 100:1504–10

10. Ueda W, Sagara Y, Hirakawa M: Role of afferent neural input in regression of sensory paralysis during epidural block. Anesth Analg 1992; 74:358–61

11. Cousins MJ, Bromage P: Epidural neural blockade, Neural Blockade, 2nd edition. Edited by Cousins MJ, Bridenbaugh PO. Philadelphia, JB Lippincott, 1988, pp 253–360

12. Jorgensen H, Formsgaard JS, Dirks J, Wetterslev J, Andreasson B, Dahl JB: Effect of epidural bupivacaine vs combined epidural bupivacaine and morphine on gastrointestinal function and pain after major gynecological surgery. Br J Anesth 2001; 87:727–32

13. Sakura S, Sumi M, Kushizaki H, Saito Y, Kosaka Y: Concentration of lidocaine affects intensity of sensory block during lumbar epidural anesthesia. Anesth Analg 1999; 88:123–7

14. Camann W, Loferski B, Fanciullo G, Stone M, Datta S: Does epidural administration of butorphanol offer any clinical advantage over the intravenous route? ANESTHESIOLOGY 1992; 76:216–20