Patient-Controlled Epidural Analgesia for Labor

Stephen H. Halpern, MD, MSc, FRCPC*

> Brendan Carvalho, MBBCh, FRCA+

Patient-controlled epidural analgesia (PCEA) for labor was introduced into clinical practice 20 yr ago. The PCEA technique has been shown to have significant benefits when compared with continuous epidural infusion. We conducted a systematic review using MEDLINE and EMBASE (1988–April 1, 2008) of all randomized, controlled trials in parturients who received PCEA in labor in which one of the following comparisons were made: background infusion versus none; ropivacaine versus bupivacaine; high versus low concentrations of local anesthetics; and new strategies versus standard strategies. The outcomes of interest were maternal analgesia, satisfaction, motor block, and the incidence of unscheduled clinician interventions.

A continuous background infusion improved maternal analgesia and reduced unscheduled clinician interventions. Larger bolus doses (more than 5 mL) may provide better analgesia compared with small boluses. Low concentrations of bupivacaine or ropivacaine provide excellent analgesia without significant motor block. Many strategies with PCEA can provide effective labor analgesia. High volume, dilute local anesthetic solutions with a continuous background infusion appear to be the most successful strategy. Research into new delivery strategies, such as mandatory programmed intermittent boluses and computerized feedback dosing, is ongoing.

(Anesth Analg 2009;108:921-8)

Atient-controlled epidural analgesia for labor (PCEA) was first introduced into clinical practice by Gambling et al.¹ in 1988. It has proven to be both safe and effective. PCEA has many advantages when compared with continuous epidural infusion (CEI) techniques. Although the analgesia provided is similar, PCEA reduces the incidence of unscheduled clinician interventions and the total dose of local anesthetic.² PCEA also reduces the incidence of lower extremity motor block.³ Although PCEA has not consistently been associated with increased maternal satisfaction, this may be due to a lack of appropriate measuring tools. Theoretically, maternal satisfaction may be increased by allowing the parturient greater control over her analgesia.⁴ Compared with CEI, PCEA has no

Copyright © 2009 International Anesthesia Research Society D0I: 10.1213/ane.0b013e3181951a7f

clinically significant impact on obstetric or neonatal outcomes.⁵

Clinical research has focused on refining PCEA techniques to further improve analgesia, reduce motor block, and increase maternal satisfaction, while reducing the frequency of unscheduled clinician interventions. In this overview, we will systematically review the current evidence to answer the following questions: 1) Should a background infusion be used? 2) Is ropivacaine superior to bupivacaine when used for PCEA in labor? 3) Can the volume of the PCEA bolus dose and lockout interval be manipulated to optimize analgesia? and 4) What is the impact of new techniques and technologies on current PCEA practice? In answering these questions, we hope to be able to suggest a range of appropriate settings for labor PCEA and present a glimpse into future techniques of labor analgesia maintenance.

To answer the above questions, we systematically reviewed all published, randomized, controlled trials on PCEA for labor. Studies were obtained from MEDLINE and EMBASE, published in English before April 1, 2008. We included studies that have the following intervention and control groups: 1) background infusion versus no background infusion; 2) ropivacaine versus bupivacaine; 3) high-volume bolus versus low-volume bolus and/or longer lockout interval versus shorter lockout interval; and 4) a novel approach to PCEA versus standard treatment. Each

From the *Department of Anesthesia, Sunnybrook Health Sciences Centre, University of Toronto, Toronto, Canada; and †Department of Anesthesia, Stanford University School of Medicine, Stanford, California.

Accepted for publication September 28, 2008.

Supported by Departmental Sources.

Reprints will not be available from the author.

Address correspondence to Dr. Stephen Halpern, Sunnybrook Health Sciences Centre/Women's College Hospital, 76 Grenville St., Toronto, Ontario, Canada M5S 1B2. Address e-mail to stephen.halpern@sunnybrook.ca.

References	Ν	Local anesthetic concentrations, bolus volume, and lockout interval	N/group; infusion rates	Comments	Outcomes
Paech ¹¹	50	B 0.125%, F 3 μg/mL, bolus 4 mL, lockout 15 min	N = 25; 0 mL/h N = 25; 4 mL/h	Parturients and caregivers blinded.	All outcomes reported. Higher proportion of total dose given by clinicians in the no-infusion group (17% vs 9%).
Ferrante et al. ⁸	45	B 0.125%, F 2 µg/mL, bolus 3 mL, lockout 10 min	N = 15; 0 mL/h N = 15; 3 mL/h N = 15; 6 mL/h	Double blind; mixed parity.	Maternal satisfaction was not reported. There were fewer clinician rescue bolus doses in the 6 mL/h group than the 0 or 3 mL/h group.
Petry et al. ¹²	74	B 0.125%, S 0.75 μg/ mL, E 1:800,000, bolus 3 mL, lockout 12 min	N = 37; 0 mL/h N = 37; 3 mL/h	? blinding.	All outcomes were reported. No difference between groups in any outcome.
Boselli et al. ⁶	133	R 0.1%, S 0.5 μg/mL, 5-mL bolus, 5-min lockout, total 22 mL/h including infusion	N = 34; 0 mL/h N = 34; 3 mL/h N = 32; 6 mL/h N = 33; 9 mL/h	Parturients and caregivers blinded.	All outcomes reported. No difference between groups in any outcome. No significant dose trend.
Bremerich et al. ⁷	66	R 0.16%, S 0.5 μg/mL, bolus 4 mL	N = 33; 0 mL/h N = 33; 4 mL/h	Parturients blinded. Lockout 15 min for no infusion, 20 min for infusion group. CS patients excluded (seven per group).	Clinician workload not reported. Increased incidence of pain >4/ 10 in the no-infusion group. No other differences between groups.
Missant et al. ⁹	78	R 0.15%, S 0.75 μg/ mL, bolus 4 mL, lockout 15 min	N = 38; 0 mL/h N = 40; 2 mL/h	Parturients and caregivers blinded.	All outcomes reported. More clinician interventions in the no-infusion group.
Vallejo et al. ¹⁰	127	R 0.10%, F 2 μg/mL, bolus 5 mL	N = 63; 0 mL/h N = 64; 5 mL/h	Parturients and data collectors were blinded. Lockout 15 min for no infusion, 20 min for infusion group.	All outcomes were reported. No differences in any outcomes.

 Table 1. Studies Comparing Patient-Controlled Epidural Analgesia with or Without a Background Continuous Infusion

 for Labor Analgesia

Outcomes included maternal analgesia, maternal satisfaction, motor block, and clinician workload.

B = Bupivacaine; S = Sufentanil; E = epinephrine; F = fentanyl; R = Ropivacaine; CS = cesarean delivery; N = Number of subjects analyzed for outcome measures.

study included at least one outcome of interest: maternal analgesia, maternal satisfaction, motor block, and/or clinician workload. Many of the studies included data on maternal and fetal outcome, but none showed any difference between intervention and control groups. In addition, many of the studies reported differences in total drug dose and success:demand ratios. We considered these as surrogate outcomes and only reported them to explain any differences we found in the four outcomes outlined above.

THE USE OF BACKGROUND INFUSION

There are seven studies that compared PCEA with and without background infusions.^{6–12} All of these studies were randomized, controlled trials in low-risk parturients of mixed parity. The study characteristics are shown in Table 1. Of note, the infusion rates for most of the studies were quite low, with most <5 mL/h.

All of the four outcomes were reported in five of the studies.^{6,9–12} One study did not report maternal satisfaction,⁸ and one did not report clinician workload.⁷ Only one study found a difference in analgesia: patients who received PCEA without a background infusion reported a higher incidence of intense pain (>4/10) compared with those with a background infusion.⁷ Significant motor block was uncommon in all of these studies and was not significantly different between

groups. In two of the studies, there were more clinician interventions in the no infusion group.^{8,9} One study noted that more local anesthetic was administered by clinicians to parturients in the no infusion group,¹¹ implying greater workload. None of the studies noted any differences in maternal satisfaction between groups.

These data suggest that there may be a benefit for providing a continuous background infusion to PCEA. Of interest, none of the outcomes were better in patients who received PCEA alone. A meta-analysis of five of these studies^{6-9,12} reported in the American Society of Anesthesiologists' Practice Guidelines for Obstetric Anesthesia support the view that a background infusion provides better analgesia² (Odds ratio = 3.33, 95% confidence interval 1.87-5.92), although the statistical significance was not stated. An additional study comprising 300 patients randomized to 0.08% ropivacaine and 2 μ g/mL fentanyl PCEA with or without a background infusion of 10 mL/h, reported better analgesia scores in the group with a background infusion.* Although many of the studies reported reduced requirement of local anesthetics when the background infusion is omitted,^{6,10} there

^{*}Campbell DC, Breen TW, Halpern S, Muir H, Nunn R. Determination of the efficacy of PCEA alone compared to PCEA + CEIA using ambulatory labor analgesics. Anesthesiology 2004;101:supp A1210.

were neither reports of toxicity nor any impact on the incidence of motor block.

The most consistent benefit of a background infusion is to reduce the number of unscheduled clinician interventions. This is of greatest benefit in busy settings where clinicians are unable to reliably provide epidural clinician rescue bolus doses in a timely fashion. Under the study conditions reported above, there was no difference in maternal satisfaction related to delays in obtaining analgesia.

In summary, a background infusion reduces the incidence of unscheduled clinician interventions and may improve patient analgesia. None of the studies reported an increase in motor block associated with the background infusion.

ROPIVACAINE VERSUS BUPIVACAINE

There are 11 studies that compare ropivacaine with bupivacaine in parturients receiving PCEA.^{13–23} Five of these were in nulliparous patients,^{13,14,18,22,23} with one study separating the results of the nulliparous and parous patients.¹⁵ The investigators and patients were blinded to study drug in all of the studies.

The characteristics of the studies and measured outcomes are shown in Table 2. Of note, there was a wide range of PCEA settings. The concentration of bupivacaine ranged from 0.05% (with fentanyl) to 0.125%. The concentration of ropivacaine ranged from 0.05% to 0.20%. Two studies used different concentrations of ropivacaine and bupivacaine in an effort to reflect differences in potency.^{15,19}

All of the studies measured maternal analgesia. Labor analgesia was similar between study groups.

All but one study reported the incidence of motor block.¹⁹ Of these studies, five reported an increased incidence of motor block associated with bupivacaine.^{13,15,16,18,20} These findings agree with data in the setting of CEI supplemented by clinician rescue bolus doses, suggesting that bupivacaine is associated with more motor block than ropivacaine.²⁴ However, most studies did not account for relative differences in potency between ropivacaine and bupivacaine.²⁵

Few studies measured maternal satisfaction.^{14,16,18,20} There were no differences in global satisfaction measures reported in any of the studies. One study found an increased satisfaction in analgesia at the time of delivery in parturients who received bupivacaine, but this was not reflected in the visual analog scale scores or global measures of satisfaction.¹⁸ The same study reported higher satisfaction scores for mobility in the ropivacaine group. Similarly, Fischer et al.¹⁶ reported increased maternal satisfaction with relief of contraction and delivery pain in patients receiving bupivacaine. These authors could not demonstrate a difference in visual analog scale scores between groups.

Six studies reported the incidence of clinician rescue bolus doses.^{14,16,18,20–22} There were no differences between groups in any of the studies. One study reported an increased incidence of clinician rescue boluses during the first stage of labor in patients who received bupivacaine, but the incidence was higher in the ropivacaine group during the second stage of labor.²⁰

In summary, both ropivacaine and bupivacaine are well suited for PCEA in labor. The most consistent finding is an increased incidence of motor block in patients receiving bupivacaine compared with ropivacaine, but this difference may not be clinically significant, particularly for short labors. Flexibility in the PCEA settings may offset any advantage that drug selection may have.

BOLUS DOSE VOLUME AND LOCKOUT INTERVAL

There are wide variations in PCEA settings in clinical practice.²⁶ Six studies have compared various PCEA settings to try to determine the ideal bolus dose and corresponding lockout time interval.^{27–32} The study characteristics are shown in Table 3. All of these studies were randomized, controlled trials in low-risk nulliparous or mixed parity populations.

Analgesia, maternal satisfaction, motor block, and clinician rescue boluses were reported in all of the studies. Studies used bupivacaine (0.0625%-0.125%) and ropivacaine (0.1%-0.2%) with fentanyl or sufentanil. Bolus volumes ranged from 2 to 20 mL and lockout intervals from 5 to 30 min. Three studies used a background infusion in addition to PCEA.^{29–31}

Only one study found that increasing the bolus volume (4–12 mL, with corresponding lockout interval of 8–25 min) improved analgesia.³² A shorter lockout interval improved the PCEA success:demand ratio in one study,³⁰ but this did not lead to a decrease in unscheduled clinician rescue boluses. None of the studies showed a significant difference in unscheduled clinician interventions. Significant motor block was uncommon in any of these studies and was not significantly different among PCEA settings. There were no reports of toxicity or increased side effects with the larger bolus volumes.

These data suggest that various regimens can produce effective labor analgesia. Most studies were underpowered to show modest outcome differences among the various settings. Bolus doses of 12 mL of dilute local anesthetic may provide better analgesia and maternal satisfaction than 4 mL boluses in parturients receiving PCEA without a background infusion.³² Large boluses improve spread in the epidural space and have been shown to improve epidural labor analgesia outside of the PCEA setting.³³ There are insufficient data to comment on the safety of large volume patient-controlled bolus doses.

Although shorter lockout intervals may improve the success:demand ratios,³⁰ this was not reflected in better analgesia or maternal satisfaction. Lockout intervals of up to 25 min did not result in any changes

References	Parity	Ν	Bupivacaine concentration, additives, and PCEA settings	Ropivacaine concentration, additives, and PCEA settings	Comments	Outcomes
Owen et al. ²¹	Mixed parity	51	B 0.125%, bolus 5 mL, lockout 10 min, infusion 6 mL/h	R 0.125%, bolus 5 mL, lockout 10 min, infusion 6 mL/h	Patient, investigators and caregivers blinded. 61 patients enrolled, 10 eliminated.	Maternal satisfaction was not measured. No difference between groups for any outcome.
Meister et al. ²⁰	Mixed parity	50	B 0.125%, F 2 µg/mL, bolus 5 mL, lockout 10 min, infusion 6 mL/h	R 0.125%, F 2 µg/mL, bolus 5 mL, lockout 10 min, infusion 6 mL/h	Patient, investigators and caregivers blinded. 70 patients enrolled in the study, 20 eliminated.	All outcomes reported. No difference in analgesia scores or maternal satisfaction. No difference in total clinician rescue bolus doses but there were more clinician topups in the bupivacaine group in 1st stage, and more topups in the ropivacaine group during 2nd stage. The incidence of motor block was reduced in the ropivacaine group.
Campbell et al. ¹³	Nulliparous	40	B 0.08%, F 2 μ g/mL, bolus 5 mL, lockout 10 min, Infusion 0	R 0.08%, F 2 μg/mL, bolus 5 mL, lockout 10 min, infusion 0	Patient, investigators and caregivers blinded.	Clinician workload and maternal satisfaction not reported. Less motor block in the ropivacaine group (ability to ambulate).
Fischer et al. ¹⁶	Mixed parity	189	B 0.1%, S 0.5 μg/mL, bolus 5 mL, lockout 10 min, infusion 0	R 0.1%, S 0.5 μg/mL, bolus 5 mL, lockout 10 min, infusion 0	Patient, investigators and caregivers blinded. 30% of the dose given by clinicians.	All outcomes reported. Maternal satisfaction was reported as "satisfaction with relief of contraction pain" for 1st and 2nd stage. No difference in analgesia but greater maternal satisfaction for 1st and 2nd stage. More clinician topups with ropivacaine. Lower incidence of motor block with ropivacaine.
Chua et al. ¹⁴	Nulliparous	32	B 0.125%, bolus 5 mL, lockout 10 min, infusion 0	R 0.125%, bolus 5 mL, lockout 10 min, infusion 0	Patient, investigators and caregivers blinded.	All outcomes reported. No difference between groups in any outcome.
Owen et al. ²²	Nulliparous	50	B 0.075%, F 2 μg/mL, bolus 5 mL, lockout 10 min, infusion 6 mL/h	R 0.075%, F 2 μg/mL, bolus 5 mL, lockout 10 min, infusion 6 mL/h	Patient, investigators and caregivers blinded. 59 patients enrolled, nine eliminated.	Maternal satisfaction not measured. No difference between groups in any outcome.
Pirbudak et al. ²³	Nulliparous	40	B 0.05%, F 1.5 μg/mL, bolus 10 mL, lockout 20 min, infusion 10 mL/h	R 0.05%, F 1.5 μg/mL, bolus 10 mL, lockout 20 min, infusion 10 mL/h	Double blind	Maternal satisfaction and clinician workload not reported. No difference between groups for analgesia or motor block.
Hofmann-Kiefer et al. ¹⁹	Mixed parity	100	B 0.125%, S 0.75 μg/mL, bolus 4 mL, lockout 20 min_infusion 0	R 0.2%, S 0.75ug/mL, bolus 4 mL, lockout 20 min, Infusion 0	Patient, investigators and caregivers blinded.	Only analgesia measured. No difference between groups.
Halpern et al. ¹⁸	Nulliparous, induced labor	555	B 0.08%, F 2 μg/mL, bolus 5 mL, lockout 10 min, infusion 5 mL/h	R 0.08%, F 2 μg/mL, bolus 5 mL, lockout 10 min, infusion 5 mL/h	Multicentered trial. Patient, investigators and caregivers blinded. Background infusion increased by 1 mL/h after each clinician bolus.	All outcomes reported. Lower incidence of motor block in the ropivacaine group at 6 h. Maternal satisfaction with mobility higher in the ropivacaine group. Greater maternal satisfaction with analgesia at delivery in the bupivacaine group. No difference in global measures of maternal satisfaction.
Evron et al. ¹⁵	Mixed parity Data analyzed separately by parity	565	B 0.125%, bolus 5 mL, lockout 20 min, infusion 5 mL/h	R 0.2%, bolus 5 mL, lockout 20 min, infusion 5 mL/h	Patient, investigators and caregivers blinded. 313 patients received B, 256 received R.	Maternal satisfaction and clinician workload not reported. Motor block less frequent and less intense in the ropivacaine group.
Gogarten et al. ¹⁷	Mixed parity	411	One group, B 0.125%, S 0.75 μg/mL, bolus 4 mL, lockout 15 min, infusion 0 mL/h	Three groups, R 0.125%, S 0.75 µg/mL or R 0.175%, S 0.75 µg/mL or R 0.2%, bolus 5 mL, lockout 15 min, infusion 0 mL/h	Multicentered trial with four groups. Patients, investigators, and clinicians blinded.	Maternal satisfaction and clinician workload not measured. No difference in analgesia or motor block (Bromage scores and RAM test).

Table 2. Studies Comparing Ropivacaine Versus Bupivacaine for Labor Patient-Controlled Epidural Analgesia

Outcomes included maternal analgesia, maternal satisfaction, motor block, and clinician workload.

B = Bupivacaine; S = Sufentanil; E = epinephrine; F = fentanyl; R = Ropivacaine; RAM = rectus abdominus muscle; N = Number of patients analyzed for outcome measures.

in either maternal satisfaction or unscheduled clinician interventions. This may have been due to the larger bolus doses used in these studies.

In summary, there remains no ideal bolus dose or lockout interval setting for labor PCEA. Large bolus doses of dilute local anesthetic may provide superior analgesia and maternal satisfaction compared with small boluses in patients who do not receive a background infusion.

DRUG CONCENTRATION

Six studies have compared various local anesthetic concentrations using a PCEA technique for labor

	Bolus volume and lockout									
References	Parity	Ν	Drug and concentration	interval	Comments	Outcomes				
Change lockout Stratmann et al. ³⁰	interval only Mixed	60	B 0.125%, F 2 μg/mL	Bolus 5 mL Lockout Group 1: 5 min Lockout Group 2: 15 min	Continuous infusion of 6 mL/h for all patients. Patients and caregivers blinded. Groups unbalanced for parity.	All outcomes measured. No significant difference in any outcomes.				
Change bolus v	olume and locko	ut inte	rval		1 5					
Gambling et al. ²⁷	Nulliparous	55	B 0.125%, F 2.5 μg/mL, E 1:400,000	Group A: bolus 2 mL, lockout 10 min Group B: bolus 3 mL, lockout 15 min Group C: bolus 4 mL, lockout 20 min Group D: bolus 6 mL, lockout 20 min	Five PCEA groups, one continuous infusion group (not reported here). No continuous infusion in the PCEA groups. Patients and investigators blinded.	All outcomes were measured. No differences between groups for any outcome.				
Bernard et al. ³²	Mixed	203	B 0.125, S 0.625 μg/mL, E 1:800,000	Group 1: bolus 4 mL, lockout 8 min Group 2: bolus 12 mL, lockout 25 min	No background infusion. Patients and investigators blinded.	Motor block was not measured. Significantly better analgesia in Group 2 at 6 and 9 cm dilation. Better maternal satisfaction in Group 2. No difference in clinician workload between groups.				
Bernard et al. ²⁸	Nulliparous	75	R 0.1%, F 1 μg/mL	Group 1: bolus 12mL Group 2: bolus 16mL Group 3: bolus 20 mL	No background infusion. Lockout 25 min for all groups. Patients and caregivers blinded. In 3 groups ($N = 75$, not reported here) the bolus was reduced by 1/2 and the concentration of R and F doubled after 4 cm dilation (see Table 4). All patients on oxytocin infusions.	All outcomes were reported. There were no differences between groups.				
Siddick- Sayyid et al. ³¹	Mixed	75	B 0.1%, F 2 μg/mL	Group A: bolus 3 mL, lockout 6 min Group B: bolus 6 mL, lockout 12 min Group C: bolus 9 mL, lockout 18 min	Background infusion 6 mL/h. Double-blind.	All outcomes were measured. No significant difference between groups for any outcome.				
Change bolus v Carvalho et al. ²⁹	olume, lockout ii Mixed	nterval 120	, and background infusion B 0.0625%, S 0.35 μg/mL	Groups A and C: bolus 6 mL, lockout 8 min Groups B and D: bolus 12 mL, lockout 16 min	Background infusion 10 mL for Groups A and B, 15 mL for Groups C and D. Patients and investigators blinded to group.	All outcomes were measured. No difference between groups for any outcome. There were more requests for discontinuation of the infusion for "perceived motor weakness" in Group D but this was not confirmed by differences in Bromage scores.				

Table 3. Stu	lies Comparing	Bolus Volumes	and Lockout	Intervals for	Labor	Patient-Controlled	Epidural	Analgesia
--------------	----------------	----------------------	-------------	---------------	-------	--------------------	----------	-----------

Outcomes included maternal analgesia, maternal satisfaction, motor block, and clinician workload.

B = Bupivacaine; S = Sufentanil; E = epinephrine; F = fentanyl; R = Ropivacaine; N = Number of patients analyzed for outcome measures.

analgesia.^{17,28,34–37} The study characteristics are shown in Table 4. All of these studies were randomized controlled trials in low-risk nulliparous or mixed parity study populations. Studies used bupivacaine (0.0625%-0.25%) and ropivacaine (0.1%-0.2%) with fentanyl or sufentanil.

No differences in the efficacy of labor analgesia provided by the various solutions were reported in any of these studies. Four studies found increased local anesthetic use in the high-concentration local anesthetic groups.^{17,34–36} Local anesthetic dose reduction with the more dilute solutions ranged from 35% to 75%. The more concentrated solution groups resulted in significantly greater motor block in three of the studies.^{17,35,37} Two studies found less pruritus with local anesthetic without opioids.^{17,36} Two studies found higher PCEA success:demand ratios with the more concentrated solutions.^{35,37}

These data demonstrate that the use of dilute local anesthetic solutions with opioids for labor PCEA results in less local anesthetic consumption and motor block without compromising labor analgesia. Reductions in local anesthetic consumption with more dilute local anesthetic solutions in these PCEA studies echoes the results of studies that compared high and low-dose solutions for initiation of epidural labor analgesia.³³ For example, the minimum local analgesic dose (or ED₅₀) of bupivacaine 0.125% was 25% lower than the minimum local analgesic dose of bupivacaine 0.25% for the initiation of labor analgesia.³³ A possible explanation for this finding is that studies that used more dilute solutions also used larger volumes. The larger volumes may improve analgesia as a result of more uniform anesthetic spread in the epidural space.³⁸ Similar to the finding that the addition of lipophilic

Table 4.	Studies	Comparing	Different	Concentrations	of	Local	Anesthetics	for	Patient-Controlled	Epidural	Analgesia	in	Labo

References	Parity	Ν	Drug and concentration	Bolus volume and lockout interval	Comments	Outcomes
Paech ³⁵	Mixed	66	Group 1: B 0.25% Group 2: B 0.125% + F 3 μg/mL Group 3: B 0.0625% + F 3 μg/mL + E 1:250.000	Bolus 4 mL, lockout 15 min	Double-blinded. No background infusion	No differences in pain relief, satisfaction, rescue boluses, or side-effects. More motor block in B 0.25% group.
Sia et al. ³⁷	Nulliparous	50	Group 1: R 0.125% Group 2: R 0.2%	Bolus 5 mL, lockout 10 min	Investigator-blinded. No background infusion	All outcomes were reported. Greater motor block in R 0.2% group.
Bernard et al. ²⁸	Nulliparous	75	Group 1: R 0.1%, F 0.5 μg/mL Group 2: R 0.2%, F 1 μg/mL	Group 1: bolus 12, 16, and 20 mL Group 2: bolus 6, 8, and 10 mL	No background infusion. Lockout 25 min for all groups. Patients and caregivers blinded. After 4 cm dilation. All patients on oxytocin infusions.	All outcomes were reported. There were no differences between groups.
Boselli et al. ³⁴	Mixed	130	Group 1: R 0.15% + S 0.5 μg/mL Group 2: R 0.1% + S 0.5 μg/mL	Bolus 5 mL, lockout 5 min	Double-blind; 10 mL/h background infusion	All outcomes were reported. No differences in outcomes.
Gogarten et al. ¹⁷	Mixed	411	Group 1: R 0.125% + S 0.75 μg/mL Group 2: R 0.175% + S 0.75 μg/mL Group 3: R 0.2% Group 4: B 0.125% + S 0.75 μg/mL	Bolus 4 mL, lockout 15 min	Double-blind; No background infusion.	All outcomes except clinician rescue boluses were reported. Increase incidence of motor block (as measured by Bromage Scale but not by RAM test) in the 0.2% R group at 2 h.
Nikkola et al. ³⁶	Nulliparous	57	Group 1: B 0.0625% + F 7.5 μg/mL Group 2: B 0.125%	Bolus 2 mL, lockout 10 min	No background infusion. Blinding not mentioned but the midwives were told to "treat all mothers in every group like regular parturients." 3rd group (intermittent clinician boluses) also reported.	All outcomes except motor block were reported. More local anesthetic use and less pruritus in the B 0.125% group. Satisfaction in both groups was less than the clinician bolus group because of inadequate dosing.

Outcomes included maternal analgesia, maternal satisfaction, motor block, and clinician workload.

B = Bupivacaine; F = Fentanyl; S = Sufentanil; E = Epinephrine; N = Number of patients analyzed for outcome measures; RAM = rectus abdominus muscle.

opioids (e.g., fentanyl or sufentanil) to local anesthetics results in a dose-dependent reduction in the minimum local analgesic concentration of bupivacaine,³⁹ their use also improves the quality of analgesia during labor PCEA.⁴⁰ However, lipophilic opioids may result in dose-dependent pruritus.⁴⁰

In summary, when using labor PCEA, dilute local anesthetic solutions should be used. The use of 0.25% bupivacaine and 0.2% ropivacaine will lead to an increased incidence of motor blockade without concomitant increases maternal analgesia or satisfaction. The lowest, clinically effective, concentration of lipophilic opioid should be added to avoid excessive pruritus.

FUTURE DEVELOPMENTS

Computer-Integrated PCEA

Computer-integrated PCEA is a novel epidural solution delivery system that automatically adjusts the background infusion rate based on the number of PCEA demands.^{41,42} The authors who devised this system connected a laptop computer with a programmed algorithm to a standard epidural infusion

pump. The computer-integrated PCEA algorithm adjusts the background infusion to 5, 10, or 15 mL/h if the patient require one, two, or three demand boluses, respectively, in the previous hour and decreases the background infusion by increments of 5 mL/h if there are no bolus demands in the previous hour.41 In theory, a system that responds to patient's analgesic requirements should improve efficacy while minimizing increases in local anesthetic use-associated background infusions. Initial studies with this system have been encouraging.^{41,42} One study compared demandonly PCEA with a similar PCEA regimen with the computer-integrated background infusion.⁴¹ The computer-integrated PCEA group had similar local anesthetic consumption compared with demand-only PCEA but was associated with increased maternal satisfaction. Another study found that computerintegrated PCEA reduced the incidence of breakthrough pain without increasing drug consumption when compared with CEI without PCEA for labor analgesia.42 Computer-integrated PCEA is not currently commercially available but may be incorporated in future epidural pumps.

Programmed Intermittent or Automated Mandatory Epidural Boluses

A recent development that may change the way PCEA is administered is programmed intermittent epidural boluses (PIEB). Instead of a CEI, the same total hourly amount of local anesthetic is administered as intermittent boluses (e.g., two boluses of 6 mL every 30 min vs 12 mL/h CEI). PIEB has been shown to be more effective than CEI for labor analgesia.^{43–45} The PIEB resulted in similar analgesia, higher maternal satisfaction, and less need for unscheduled clinician rescue boluses. The technique also resulted in less bupivacaine use for maintenance of epidural labor analgesia. A mechanism proposed for the local anesthetic-sparing effect of PIEB is a more uniform epidural spread of local anesthetics when large volumes of local anesthetic (with correspondingly high injectate pressures) are delivered.38 Recently, PIEB combined with PCEA were compared with PCEA with a standard continuous background infusion.⁴⁶ The PIEB resulted in reduced consumption of ropivacaine and less PCEA demand boluses while maintaining similar analgesic efficacy. The PIEB function is currently not available, but the technology will be incorporated with future improvements in electronic epidural devices.

Disposable Epidural PCEA

The past decade has seen vast improvements in disposable local anesthetic infusion devices, driven mainly by the increase in ambulatory nerve block and wound instillation techniques. In the labor setting, a simple disposable PCEA device has been compared with a standard electronic PCEA device for labor analgesia.⁴⁷ The authors found no significant differences in analgesic efficacy, maternal satisfaction, local anesthetic use, or side effects. Disposable devices are less bulky than electronic devices, which may facilitate ambulation during labor. The main disadvantages with disposable devices are the lack of programmability and potentially increased costs.

SUMMARY

PCEA is a reliable and effective method of maintaining epidural labor analgesia. Provided that sufficient drug volumes are allowed, a wide variety of drug combinations and settings have been used successfully. Low concentrations of bupivacaine or ropivacaine with opioids provide excellent analgesia. Motor block can be minimized by using dilute local anesthetic solutions (up to 0.125% bupivacaine or 0.2% ropivacaine). A background infusion is suitable for most patients because it reduces the need for unscheduled clinician interventions and may provide better analgesia compared with when a background infusion is omitted. Background infusion rates between 2 and 10 mL/h have been used effectively. There remains no ideal bolus dose or lockout interval setting for labor PCEA. Larger bolus doses (more than 5 mL) of dilute local anesthetic may provide superior

analgesia compared with small boluses. Research into new delivery strategies, such as mandatory programmed intermittent boluses and computerized feedback dosing, is ongoing.

REFERENCES

- 1. 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 Anaesth 1988;35:249–54
- American Society of Anesthesiologists Task Force on Obstetric Anesthesia. Practice guidelines for obstetric anesthesia: an updated report by the American Society of Anesthesiologists Task Force on Obstetric Anesthesia. Anesthesiology 2007;106:843–63
- Halpern SH. Maintenance of epidural analgesia for laborcontinuous infusion or patient control. In: Halpern SH, Douglas MJ, eds. Evidence-based obstetric anesthesia. Malden, MA: Blackwell publishing, 2004:23–9
- Hodnett ED. Pain and women's satisfaction with the experience of childbirth: a systematic review. Am J Obstet Gynecol 2002;186(5 suppl):S160–S172
- 5. van der Vyver M, Halpern S, Joseph G. Patient-controlled epidural analgesia versus continuous infusion for labour analgesia: a meta-analysis. Br J Anaesth 2002;89:459–65
- Boselli E, Debon R, Cimino Y, Rimmele T, Allaouchiche B, Chassard D. Background infusion is not beneficial during labor patient-controlled analgesia with 0.1% ropivacaine plus 0.5 microg/ml sufentanil. Anesthesiology 2004;100:968–72
- Bremerich DH, Waibel HJ, Mierdl S, Meininger D, Byhahn C, Zwissler BC, Ackermann HH. Comparison of continuous background infusion plus demand dose and demand-only parturient-controlled epidural analgesia (PCEA) using ropivacaine combined with sufentanil for labor and delivery. Int J Obstet Anesth 2005;14:114–20
- Ferrante FM, Rosinia FA, Gordon C, Datta S. The role of continuous background infusions in patient-controlled epidural analgesia for labor and delivery. Anesth Analg 1994;79:80–4
- Missant C, Teunkenst A, Vandermeersch E, Van de Velde M. Patient-controlled epidural analgesia following combined spinal-epidural analgesia in labour: the effects of adding a continuous epidural infusion. Anaesth Intensive Care 2005; 33:452–6
- Vallejo MC, Ramesh V, Phelps AL, Sah N. Epidural labor analgesia: continuous infusion versus patient-controlled epidural analgesia with background infusion versus without a background infusion. J Pain 2007;8:970–5
- 11. Paech MJ. Patient-controlled epidural analgesia in labour—is a continuous infusion of benefit? Anaesth Intensive Care 1992;20:15–20
- Petry J, Vercauteren M, Van Mol I, Van Houwe P, Adriaensen HA. Epidural PCA with bupivacaine 0.125%, sufentanil 0.75 microgram and epinephrine 1/800.000 for labor analgesia: is a background infusion beneficial? Acta Anaesthesiol Belg 2000;51:163–6
- Campbell DC, Zwack RM, Crone LA, Yip RW. Ambulatory labor epidural analgesia: bupivacaine versus ropivacaine. Anesth Analg 2000;90:1384–9
- Chua NP, Sia AT, Ocampo CE. Parturient-controlled epidural analgesia during labour: bupivacaine vs. ropivacaine. Anaesthesia 2001;56:1169–73
- 15. Evron S, Glezerman M, Sadan O, Boaz M, Ezri T. Patientcontrolled epidural analgesia for labor pain: effect on labor, delivery and neonatal outcome of 0.125% bupivacaine vs 0.2% ropivacaine. Int J Obstet Anesth 2004;13:5–10
- Fischer C, Blanie P, Jaouen E, Vayssiere C, Kaloul I, Coltat JC. Ropivacaine, 0.1%, plus sufentanil, 0.5 microg/ml, versus bupivacaine, 0.1%, plus sufentanil, 0.5 microg/ml, using patientcontrolled epidural analgesia for labor: a double-blind comparison. Anesthesiology 2000;92:1588–93
- 17. Gogarten W, Van de Velde M, Soetens F, Van Aken H, Brodner G, Gramke HF, Soetens M, Marcus MA. A multicentre trial comparing different concentrations of ropivacaine plus sufentanil with bupivacaine plus sufentanil for patientcontrolled epidural analgesia in labour. Eur J Anaesthesiol 2004;21:38–45

- Halpern SH, Breen TW, Campbell DC, Muir HA, Kronberg J, Nunn R, Fick GH. A multicenter, randomized, controlled trial comparing bupivacaine with ropivacaine for labor analgesia. Anesthesiology 2003;98:1431–5
- Hofmann-Kiefer K, Saran K, Brederode A, Bernasconi H, Zwissler B, Schwender D. Ropivacaine 2 mg/mL vs. bupivacaine 1.25 mg/mL with sufentanil using patient-controlled epidural analgesia in labour. Acta Anaesthesiol Scand 2002;46:316–21
- 20. Meister GC, D'Angelo R, Owen M, Nelson KE, Gaver R. A comparison of epidural analgesia with 0.125% ropivacaine with fentanyl versus 0.125% bupivacaine with fentanyl during labor. Anesth Analg 2000;90:632–7
- Owen MD, D'Angelo R, Gerancher JC, Thompson JM, Foss ML, Babb JD, Eisenach JC. 0.125% ropivacaine is similar to 0.125% bupivacaine for labor analgesia using patient-controlled epidural infusion. Anesth Analg 1998;86:527–31
- Owen MD, Thomas JA, Smith T, Harris LC, D'Angelo R. Ropivacaine 0.075% and bupivacaine 0.075% with fentanyl 2 microg/mL are equivalent for labor epidural analgesia. Anesth Analg 2002;94:179–83
- Pirbudak L, Tuncer S, Kocoglu H, Goksu S, Celik C. Fentanyl added to bupivacaine 0.05% or ropivacaine 0.05% in patientcontrolled epidural analgesia in labour. Eur J Anaesthesiol 2002;19:271–5
- 24. Halpern SH, Walsh V. Epidural ropivacaine versus bupivacaine for labor: a meta-analysis. Anesth Analg 2003;96:1473–9
- Casati A, Putzu M. Bupivacaine, levobupivacaine and ropivacaine: are they clinically different? Best Pract Res Clin Anaesthesiol 2005;19:247–68
- Carvalho B, Wang P, Cohen SE. A survey of labor patientcontrolled epidural anesthesia practice in California hospitals. Int J Obstet Anesth 2006;15:217–22
- 27. Gambling DR, Huber CJ, Berkowitz J, Howell P, Swenerton JE, Ross PL, Crochetiere CT, Pavy TJ. Patient-controlled epidural analgesia in labour: varying bolus dose and lockout interval. Can J Anaesth 1993;40:211–7
- Bernard JM, Le Roux D, Frouin J. Ropivacaine and fentanyl concentrations in patient-controlled epidural analgesia during labor: a volume-range study. Anesth Analg 2003;97:1800–7
- Carvalho B, Cohen SE, Giarrusso K, Durbin M, Riley ET, Lipman S. "Ultra-light" patient-controlled epidural analgesia during labor: effects of varying regimens on analgesia and physician workload. Int J Obstet Anesth 2005;14:223–9
- 30. Stratmann G, Gambling DR, Moeller-Bertram T, Stackpole J, Pue AF, Berkowitz J. A randomized comparison of a five-minute versus fifteen-minute lockout interval for PCEA during labor. Int J Obstet Anesth 2005;14:200–7
- Siddik-Sayyid SM, Aouad MT, Jalbout MI, Zalaket MI, Mouallem MR, Massouh FM, Rizk LB, Maarouf HH, Baraka AS. Comparison of three modes of patient-controlled epidural analgesia during labour. Eur J Anaesthesiol 2005;22:30–4
- 32. Bernard JM, Le Roux D, Vizquel L, Barthe A, Gonnet JM, Aldebert A, Benani RM, Fossat C, Frouin J. Patient-controlled epidural analgesia during labor: the effects of the increase in bolus and lockout interval. Anesth Analg 2000;90:328–32

- 33. Lyons GR, Kocarev MG, Wilson RC, Columb MO. A comparison of minimum local anesthetic volumes and doses of epidural bupivacaine (0.125% w/v and 0.25% w/v) for analgesia in labor. Anesth Analg 2007;104:412–5
- 34. Boselli E, Debon R, Duflo F, Bryssine B, Allaouchiche B, Chassard D. Ropivacaine 0.15% plus sufentanil 0.5 microg/mL and ropivacaine 0.10% plus sufentanil 0.5 microg/mL are equivalent for patient-controlled epidural analgesia during labor. Anesth Analg 2003;96:1173–7
- 35. Paech MJ. Patient controlled epidural analgesia during labour: choice of solution. Int J Obstet Anesth 1993;2:65–71
- Nikkola E, Laara A, Hinkka S, Ekblad U, Kero P, Salonen M. Patient-controlled epidural analgesia in labor does not always improve maternal satisfaction. Acta Obstet Gynecol Scand 2006;85:188–94
- Sia AT, Ruban P, Chong JL, Wong K. Motor blockade is reduced with ropivacaine 0.125% for parturient-controlled epidural analgesia during labour. Can J Anaesth 1999;46:1019–23
- Hogan Q. Distribution of solution in the epidural space: examination by cryomicrotome section. Reg Anesth Pain Med 2002;27:150-6
- Polley LS, Columb MO, Wagner DS, Naughton NN. Dosedependent reduction of the minimum local analgesic concentration of bupivacaine by sufentanil for epidural analgesia in labor. Anesthesiology 1998;89:626–32
- Bernard JM, Le Roux D, Barthe A, Jourdain O, Vizquel L, Michel C. The dose-range effects of sufentanil added to 0.125% bupivacaine on the quality of patient-controlled epidural analgesia during labor. Anesth Analg 2001;92:184–8
- Lim Y, Sia AT, Ocampo CE. Comparison of computer integrated patient controlled epidural analgesia vs. conventional patient controlled epidural analgesia for pain relief in labour. Anaesthesia 2006;61:339–44
- 42. Sia AT, Lim Y, Ocampo CE. Computer-integrated patientcontrolled epidural analgesia: a preliminary study on a novel approach of providing pain relief in labour. Singapore Med J 2006;47:951–6
- Wong CA, Ratliff JT, Sullivan JT, Scavone BM, Toledo P, McCarthy RJ. A randomized comparison of programmed intermittent epidural bolus with continuous epidural infusion for labor analgesia. Anesth Analg 2006;102:904–9
- 44. Lim Y, Sia AT, Ocampo C. Automated regular boluses for epidural analgesia: a comparison with continuous infusion. Int J Obstet Anesth 2005;14:305–9
- 45. Chua SM, Sia AT. Automated intermittent epidural boluses improve analgesia induced by intrathecal fentanyl during labour. Can J Anaesth 2004;51:581–5
- 46. Sia AT, Lim Y, Ocampo C. A comparison of a basal infusion with automated mandatory boluses in parturient-controlled epidural analgesia during labor. Anesth Analg 2007;104:673–8
- 47. Sumikura H, van de Velde M, Tateda T. Comparison between a disposable and an electronic PCA device for labor epidural analgesia. J Anesth 2004;18:262–6