

Prediction of Effective Post-Operative Epidural Anesthesia Using Hemodynamic Changes Detected by Endotracheal Cardiac Output Monitor (ECOM)

B Ahlgren, F Puskas, C Dingmann, T Seres

Citation

B Ahlgren, F Puskas, C Dingmann, T Seres. *Prediction of Effective Post-Operative Epidural Anesthesia Using Hemodynamic Changes Detected by Endotracheal Cardiac Output Monitor (ECOM)*. The Internet Journal of Anesthesiology. 2012 Volume 30 Number 4.

Abstract

Background: Epidural anesthesia after abdominal surgery results in improved postoperative pain relief but has up to a 30% failure rate. Hemodynamic changes after epidural administration of local anesthetics may provide parameters to predict dermatomal blockade and effective pain control in the postoperative period. The Endotracheal Cardiac Output Monitor (ECOM) provides continuous measurements of stroke volume (SV), cardiac output (CO) cardiac index (CI) and systemic vascular resistance (SVR). We hypothesized that the changes in hemodynamic parameters measured by the ECOM monitor along with changes in systolic (SBP), diastolic (DBP) and mean arterial pressure (MAP) would predict effective epidural anesthesia. **Methods:** 19 patients undergoing intra-abdominal surgery were enrolled. After placement of an epidural catheter and establishment of general anesthesia hemodynamics were recorded in 15-minute intervals using the ECOM monitor. At the start of abdominal closure epidural catheters were loaded with two 5 ml boluses of 0.25% bupivacaine in ten-minute intervals. Hemodynamic parameters were then recorded at five-minute intervals until conclusion of surgery. The number of dermatomes blocked, post anesthesia care unit (PACU) pain scores, average 24-hour pain scores, and patient satisfaction were recorded. **Results:** Significant reduction was observed in SBP, DBP, MAP and in SVR, and increases were seen in CO and CI after starting epidural anesthesia. From the parameters measured, only a significant reduction of SVR accompanied with higher level of dermatomes blocked, and lower average 24-hour pain scores. At the same time patients without significant SVR change had relatively low pain scores, high patient satisfaction and required the same amount of pain medications. **Conclusion:** Changes in SVR detected by the ECOM monitor might help to predict an effective epidural system but its clinical relevance needs to be further evaluated.

INTRODUCTION

General anesthesia combined with post operative epidural analgesia for major intra-abdominal surgery results in superior post-operative pain relief, improved mental status, faster return of bowel function, and accelerated patient recovery after surgery, compared with general anesthesia followed by parenteral opioids (1-4). Failure of epidural anesthesia is defined as inadequate pain relief that requires either repositioning or replacement of the catheter, change of medication, or addition of another major pain relief modality (e.g., i.v. PCA). In three major studies with patient populations ranging from 1,000 to 25,000 the failure rate was reported as low as 3%, to as high as 30% (5-7). Epidural failures are attributed to either mal position of catheters not in the epidural space or patient specific anatomy that does not allow equal spread of epidural infusion volumes (5-7). Therefore a potentially large proportion of patients are not

experiencing the above mentioned benefits of epidural anesthesia. Although different techniques have been advocated including the use of fluoroscopy, and pre-operative bolusing of catheters, the optimal method for pre or intra-operative determination of a working epidural catheter has yet to be elucidated (8, 9). In this pilot study a novel cardiac output monitor was used to measure hemodynamic changes after bolus administration of local anesthetics into the epidural catheter to evaluate the effectiveness of epidural anesthesia.

The Endotracheal Cardiac Output Monitor (ECOM), (Conmed, Irvine, CA) delivers a stable current (2 mA at 100 kHz) through the tracheal mucosa to the ascending aorta and records impedance changes associated with systolic ejection. From the change of impedance the stroke volume (SV) is determined and cardiac output (CO), systemic vascular

resistance (SVR) are calculated real time by using the systolic (SBP), diastolic (DBP), mean arterial blood pressure (MABP) values from arterial line and estimated central venous pressure (CVP) values. Animal studies suggest that the ECOM is safe and accurate in CO determination (10). To date this device has only been studied in the cardiac surgery patient population. Comparison of CO measurements between the ECOM monitor and the more traditional thermodilution (TD) or transesophageal echocardiographic (TEE) techniques has shown poor correlation in absolute values; however, trending analysis yielded 88%, and 100% of CO changes were within 0.5 L/min and 1.0 L/min limits of agreement, respectively (11, 12).

This pilot study was designed to determine the role of hemodynamic changes measured by the ECOM monitor in predicting functional epidural systems. The effectiveness of the epidural systems was compared between patients with and without significant hemodynamic changes.

METHODS

The study was accepted by University of Colorado IRB with informed consent, and was funded entirely by an internal departmental research grant. Nineteen patients undergoing intra-abdominal surgery, who accepted an epidural catheter for post-operative pain relief and an arterial line for hemodynamic monitoring, were enrolled into this study. Placement of epidural catheters occurred in the pre-anesthesia area and was performed by either intra-operative providers or members of the acute pain team. All catheters were placed in awake, alert patients lightly sedated with provider choice of intravenous midazolam, fentanyl or combination of the two. The actual placement technique was up to the individual provider. The level of placement of all catheters was between T7- L1. After placement of an epidural catheter and establishment of general anesthesia, systolic, diastolic and mean blood pressures (SBP, DBP, MAP), stroke volume (SV), cardiac output (CO), cardiac index (CI), and systemic vascular resistance (SVR), were monitored and manually recorded in 15 minute intervals using the ECOM monitor. The ECOM monitor was connected to a special endotracheal tube and to a radial arterial line transducer. The SV measurement was derived from the electrodes placed on the endotracheal tube. The electrodes represented a complex electronic system for measuring the changes of the impedance in the ascending aorta, which correlates with the actual SV. For the exact timing of the impedance measurement and for calculating

the SVR the system was connected to an arterial line transducer and measured the SBP, SDP and MAP. The patients did not have a central line for this study so a CVP value of 10 mmHg was placed into the system in order to calculate SVR. At the start of abdominal closure the epidural catheters were bolused with 5 ml of 0.25% bupivacaine in ten-minute intervals for a total of 10 ml volume. The hemodynamic parameters were then manually recorded at five-minute intervals until the conclusion of surgery. In the post anesthesia care unit (PACU) the level of dermatomal blockade, with each vertebral level accounting for two dermatomes based on left and right sided blockade, was assessed by using an ice bag to determine temperature discrimination at 20 minutes after arrival. Epidural infusions were started in PACU on all patients with either 0.08% or 0.1% bupivacaine with the addition of 6-10 mcg/ml hydromorphone. Infusion rates were started at between 8 and 10ml/hr based on the extent of incision and the localization of pain. Pain was assessed throughout the study period (every 4 hours, for 24 hours) using a visual analog scale (VAS) with 0 having no pain and 10 having the worst pain imaginable. Patient satisfaction was also evaluated on a 0-10 scale from being unsatisfied (0) to very satisfied (10) with the pain management. All patients were transferred to either the surgical intensive care unit or general surgical floor. Patients were followed by acute pain team personnel until discontinuation of the epidural catheter. The epidural infusion rates were adjusted from 6-14 ml/hr according to the dermatomal level of the block and VAS pain score.

The number of dermatomes blocked at 20 minutes from PACU arrival, the average PACU VAS pain scores, 24-hour epidural medication amounts, average 24-hour VAS pain score, and patient satisfaction score were recorded at 24 hours post-operatively.

STATISTICAL ANALYSIS

The values are expressed as mean \pm standard deviation. For statistical analyses, a paired Student's t-test was used to compare data before and after the epidural boluses. The dermatome levels, pain scores, epidural infusion and satisfaction were compared between patients with significant changes in individual hemodynamic parameters (CO, CI, SVR, SBP, DBP, MAP) and patients with non-significant changes by using an unpaired Student's t-test. A value of $p < 0.05$ was considered to be statistically significant. The equality of variances was evaluated by the Levene's test. The statistical analysis was performed by SPSS version 9

statistical program.

RESULTS

Twelve males and 7 females were enrolled into the study. Average age of patients was 58.8 ± 9.1 years. Diagnosis included: pancreatic cancer (6), rectal cancer (2), renal cancer (2), colon cancer (2), failed gastric bypass, tubular adenoma, gastrointestinal stromal cell tumor, abdominal liposarcoma, duodenal polyps, pseudomyxoma peritonei, and ulcerative colitis. Dictated procedures included: whipple (6), nephrectomy (2), distal pancreatectomy/splenectomy, right hepatectomy, duodenal resection, antero-posterior resection, abdominoperoneal resection, revision of gastric bypass, small bowel resection, colon resection, radiofrequency hepatic ablation/adrenalectomy, ileo-anal pull-through, and abdominal debulking. Average loss of resistance with epidural placement occurred at 6.6 ± 1.4 cm, with catheters secured to skin at an average of 11.8 ± 1.3 cm. Eleven of 19 catheters were recorded as easy placement, 7/19 required more than one attempt and 1/19 required movement of needle insertion to different vertebral level. All test doses were reported negative with no immediate complications from insertion.

The hemodynamic values were averaged before and after the epidural bolus injection and paired Student's t-test was used to calculate the significance of the difference in each patient. A significant reduction was observed in SBP, DBP, MAP, SVR, with increases seen in CO, and CI after starting epidural anesthesia. No significant change in SV or HR was observed (Table 1). It was hypothesized that significant change in each of the hemodynamic parameters (SBP, DBP, MAP, SVR, CO, CI) in individual patients might predict a functional epidural catheter and effective postoperative pain relief. The dermatome level, average PACU VAS pain score, average 24-hour VAS pain score and patient satisfaction score were compared in patients with or without significant changes of each of the above hemodynamic values. Patients with significant change in SBP, DBP, MAP, CO or CI did not show any correlation with dermatome level or any of the measured pain scores. Significant SVR reduction was the only hemodynamic parameter, which was associated with higher dermatomal blockade and decreased pain scores. Significant SVR reduction was observed in 12 patients (Group I) and non-significant change was detected in 7 patients (Group II). The number of dermatomes blocked at 20 minutes post PACU arrival was significantly higher and the average 24-hour VAS pain score was significantly lower

in Group I (Table 2). The average PACU VAS pain score and patient satisfaction score were not statistically different between the two groups. There was no significant difference between groups I and II in the dose of epidural bupivacaine or epidural hydromorphone received in the first 24 hours post-operatively (Table 2).

Figure 1

Table 1: Hemodynamic changes associated with epidural bolus administration of 10 ml bupivacaine 0.25%

	Pre Bolus	Post Bolus	p value
Systolic Blood Pressure (mmHg)	106.9 ± 7.2	99.8 ± 11.9	<0.02
Diastolic Blood Pressure (mmHg)	56.8 ± 6.1	50.4 ± 7.4	<0.002
Mean Arterial Blood Pressure (mmHg)	73.5 ± 5.8	66.8 ± 8.3	<0.003
Systemic Vascular Resistance (dyn·s/cm ⁵)	905.7 ± 183.6	726.8 ± 139.1	<0.001
Stroke Volume (ml)	77.6 ± 11.7	79.8 ± 12.9	0.180
Heart Rate (BPM)	72.1 ± 9.9	73.2 ± 12.3	0.409
Cardiac Output (L/min)	5.6 ± 0.8	5.9 ± 0.9	<0.02
Cardiac Index (L/min/m ²)	2.8 ± 0.4	2.9 ± 0.4	<0.03

Significant differences defined as $p < 0.05$ using paired Student's t-test

Figure 2

Table 2: Patients divided into two groups based on the presence (Group I) or absence

	Group I	Group II	p
Number of patients	12	7	
Number of dermatomes blocked	20.5 ± 4.1	11.7 ± 7.3	<0.005
Average PACU pain score	2.4 ± 2.1	3.0 ± 2.7	0.617
Average 24 hour pain score	2.2 ± 1.5	3.8 ± 1.7	<0.05
Patient satisfaction	8.3 ± 2.3	8.0 ± 2.5	0.772
24 hr epidural bupivacaine (mg)	215.3 ± 42.7	207.4 ± 31.9	0.688
24 hr epidural hydromorphone (mcg)	1501.8 ± 430.1	1394 ± 369.6	0.577

Significant difference defined as $p < 0.05$ based on unpaired Student's t-test

(Group II) of significant reduction in SVR after bolusing of epidural catheter

DISCUSSION

Epidural catheterization and local anesthetic administration causes a segmental blockade of nervous fibers in the affected dermatomes. Segmental blockade is proportional to the volume of injectant while differential blockade is based on the concentration of local anesthetic. Small unmyelinated sympathetic fibers are blocked first, followed by sensory fibers and finally large myelinated motor fibers being the most resistant to blockade. Sympathetic nerve blockade leads to a decrease in SVR, SBP, DBP, MAP, and if compensatory mechanisms are intact an increase in CO, and CI (13-16). In our study, 10 ml bupivacaine 0.25% as a loading dose induced the above pattern of hemodynamic changes as detected by the ECOM monitor. In previous studies the CO measurements of the ECOM monitor, compared to TD or TEE values in cardiac surgery patients,

have shown poor correlation in absolute values but the trending values were found to be acceptable compared with both TD and TEE derived CO measurements (11,12). These results might reflect the fact that the ECOM monitor is more reactive to rapid changes (beat to beat calculation of SV and CO) whereas the values of thermodilution measurement are updated and averaged from 30-second time periods. Despite potential limitations of the ECOM monitor it seemed a reasonable tool with appropriate sensitivity for real-time tracking of the direction and magnitude of hemodynamic changes in the setting of epidural anesthesia. The system can be used only in patients who are intubated, which is a disadvantage especially in cases where the patient is extubated in the operating room but transferred to the intensive care unit setting and potentially needs continued hemodynamic monitoring. The ECOM monitor is sensitive to electronic disturbances generated during surgery but it takes only a short time to get back to displaying the impedance curve and recording the hemodynamic numbers. The current study is the first to our knowledge using this technology in a non-cardiac surgery patient population, and also the first that uses the technology in order to attain hemodynamic indices associated with starting epidural anesthesia.

The ideal confirmation of catheter tip location and effectiveness of the epidural system are yet to be determined. Fluoroscopy can be used to accurately define the position of the catheter (8), though this method is expensive, time consuming, and may not be immediately available. Pre-operative bolusing of epidurals can also be used to assess neuraxial blockade prior to onset of general anesthesia. This technique can be used to exclude intravascular or intrathecal placement of the catheter and an anesthetized dermatome may suggest an effective epidural system. A recent study has shown that 80% of patients will have a demonstrated block of at least four dermatomal segments within eight minutes after bolusing the epidural catheter (9). In certain circumstances the pre-operative bolus may induce profound hypotension during anesthetic induction of hemodynamically unstable patients. Another common way of interrogating an epidural system is intra-operative bolusing of local anesthetic. Anesthesiologists often gain confidence of a working epidural if a decrease in blood pressure after local anesthetic bolusing is seen. It has been shown that the onset of epidural anesthesia is accompanied by decrease in SBP, DBP, as well as MAP (16). Our data supports this observation in general; however, significant

decrease in SBP, DBP, or MAP did not differentiate between patients in the effectiveness of epidural anesthesia. According to our data, serial measurement of SVR during the surgery and after a bolus injection of an epidural local anesthetic was the only hemodynamic indicator associated with increased dermatomal blockade and better 24-hour pain control.

Patients with optimal epidural anesthesia along with other benefits, usually experience effective pain relief post-operatively. In our study 12/19 (63%) of the patients had a blockade of about 20 dermatomes or 10 vertebral levels, with significant change in SVR and significantly less average 24-hour pain scores (2.2 ± 1.5) after the bolus administration of bupivacaine (Group I, Table 2). At the same time 7/19 (37%) of the patients had significantly less dermatome blockade and significantly less change in SVR (Group II, Table 2). This patient group had a blockade of about 12 dermatomes or 6 vertebral levels which may explain that although these patients had significantly higher average 24-hour VAS pain scores (3.8 ± 1.7), these scores were within the range of 1.12-3.99, which has characterized post laparotomy patients with functioning epidural anesthesia (17-19). This result may also explain why the overall patient satisfaction did not differ significantly between the two groups. There was no difference between the two groups in the amount of bupivacaine or hydromorphone infused through the epidural catheter in the first 24 hrs post-operatively suggesting that epidural anesthesia in group II might be less optimal but still effective to provide adequate pain relief characterized by low pain scores and high level of patient satisfaction. The above data suggests a limited role of hemodynamic measurements by the ECOM monitor in predicting the effectiveness of epidural anesthesia, though it may be able to predict a more extensive dermatome blockade. The cost might not be comparable to the benefits in post-operative 24 hr pain scores, patient satisfaction or the amount of medications infused through the epidural catheter.

CONCLUSION

This pilot study suggests that significant SVR change after starting epidural anesthesia may identify significantly higher dermatome blockade and reduced pain scores but it is not an absolute requirement for effective post-operative pain relief. Patients without significant SVR change may also have effective dermatome level with relatively low pain scores, high patient satisfaction and requirement of the same amount

of pain medications.

References

1. Handley G, Silbert B, Mooney P, Schweitzer S, Allen N. Combined general and epidural anesthesia versus general anesthesia for major abdominal surgery: Postanesthesia recovery characteristics. *Reg Anesth*, 1997;22:435-41.
2. Ozyuvaci E, Altan A, Karadeniz T, Topsakal M, Besisik A, Yucel M. General anesthesia versus epidural and general anesthesia in radical cystectomy. *Urol Int*, 2005; 74:62-7.
3. Mann C, Pouzeratte Y, Boccara G, Peccoux C, Vergne C, Brunat G, Domergue J, Millat B. Comparison of intravenous or epidural patient-controlled analgesia in the elderly after major abdominal surgery. *Anesthesiology*, 2000; 92:433-41
4. Rigg J, Jamrozik K, Myles P, Silbert B, Peyton P, Parsons R, Collins K. Epidural anaesthesia and analgesia and outcome of major surgery: A randomized trial. *Lancet*. 2002; 359:1276.
5. Burstal R, Wegener F, Hayes C, Lantry G. Epidural analgesia: prospective audit of 1062 patients. *Anaesth Intensive Care*. 1998;26:165-72.
6. Flisberg P, Rudin A, Linnér R, Lundberg C. Pain relief and safety after major surgery. A prospective study of epidural and intravenous analgesia in 2696 patients. *Acta Anaesthesiol Scand* 2003; 47:457-65.
7. Ready, L. Acute pain: lessons learned from 25,000 patients. *Reg Anesth Pain Med*. 1999; 24:499-505.
8. Hoshi T, Miyabe M, Takahashi S, Toyooka H. Evaluation of the Arrow Flex Tip Plus epidural catheter tip position and migration during continuous thoracic analgesia. *Can J Anaesth*.2003; 50:202-3.
9. Larsson J, Gordh T. Testing whether the epidural works: too time consuming? *Acta Anaesthesiol Scand*. 2010; 54:761-63.
10. Wallace AW, Salahieh A, Lawrence A, Spector K, Owens C, Alonso D. Endotracheal cardiac output monitor *Anesthesiology*. 2000;92:178-89.
11. Ball T, Culp B, Patel V, Gloyna D, Ciceri D, Culp W Jr. Comparison of the endotracheal cardiac output monitor to thermomodulation in cardiac surgery. patients. *J Cardiothorac Vasc Anesth*. 2010;24:762-6.
12. Maus T, Reber B, Banks D, Berry A, Guerrero E, Manecke G. Cardiac Output Determination From Endotracheally Measured Impedance Cardiography: Clinical Evaluation of Endotracheal Cardiac Output Monitor. *J of Cardiothorac and Vasc Anesthes*. 2011; [Epub ahead of print]
13. Feltracco P, Brezzi ML, Barbieri S, Serra E, Milevoj M, Ori C. Epidural anesthesia and analgesia in liver resection and living donor hepatectomy. *Transplant Proc*. 2008;40:1165-8.
14. Bakhtiary F, Therapidis P, Dzemali O, Ak K, Ackermann H, Meininger D, Kessler P, Kleine P, Moritz A, Aybek T, Dogan S. Impact of high thoracic epidural anesthesia on incidence of perioperative atrial fibrillation in off-pump coronary bypass grafting: a prospective randomized study. *J Thorac Cardiovasc Surg*, 2007;134:460-4.
15. Lundberg JF, Martner J, Raner C, Winsö O, Biber B. Dopamine or norepinephrine infusion during thoracic epidural anesthesia? Differences in hemodynamic effects and plasma catecholamine levels. *Acta Anaesthesiol Scand*, 2005;49:962-8.
16. Zhao W, Zhou R, Zhou LP, Li CH. The hemodynamic effects during thoracic epidural anesthesia combined with general anesthesia in patients undergoing major abdominal operations. *Zhonghua Wai Ke Za Zhi.*, 2009;1:849-52.
17. Mercadante S, Villari P, Casuccio A, Marrazzo A. A randomized-controlled study of intrathecal versus epidural thoracic analgesia in patients undergoing abdominal cancer surgery. *J of Clin Monit and Comput*. 2008;22:293-8.
18. Duncan, F. Prospective observational study of postoperative epidural analgesia for major abdominal surgery. *J Clin Nurs*. 2011;20:1870-9.
19. Niraj G, Kelkar A, Jeyapalan I, Graff-Baker P, Williams O, Darbar A, Maheshwaran A, Powell R. Comparison of analgesic efficacy of subcostal transversus abdominis plane blocks with epidural analgesia following upper abdominal surgery. *Anaesthesia*. 2011; 66:465-71.

Author Information

Bryan Ahlgren

University of Colorado Hospital

Ferenc Puskas

University of Colorado Hospital

Colleen Dingmann

University of Colorado Hospital

Tamas Seres

University of Colorado Hospital