The Role of Computerized Clinical Decision Support in Reducing Inappropriate Medication Administration During Epidural Therapy

Hospital Pharmacy
2018, Vol. 53(3) 170–176
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DOI: 10.1177/0018578717741392
journals.sagepub.com/home/hpx

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Abstract

Background: The use of epidural anesthesia has been shown to improve outcomes in the postoperative setting. To minimize risk of complications, avoiding certain medications with epidural anesthesia is advised. **Objective:** This study sought to determine the role of a computerized clinical decision support module implemented into the computerized physician order entry (CPOE) system on the incidence of administration of medications known to increase complications with epidural anesthesia. **Methods:** This study was a retrospective cohort chart review in adult patients receiving epidural anesthesia for at least 1 day. Patients were identified retrospectively and divided into 2 cohorts, those receiving an epidural 3 months prior to initiation of the module and those receiving an epidural 3 months following implementation. The primary end point was incidence of inappropriate medication administration before and after implementation. Complications of therapy were collected as secondary end points. **Results:** There was a reduction in the incidence of inappropriate medication administration in the postimplementation group versus the preimplementation group (6.3% vs 12.8%) although statistical significance was not achieved. In addition, the incidence of enoxaparin administration was significantly lower postimplementation than the preimplementation (0% vs 3.9%). There were no significant differences in other complications of therapy. **Conclusions:** This study demonstrated that application of decision support for this high-risk procedural population was able to eliminate the incidence of the most common inappropriate medication for epidural analgesia, enoxaparin. A reduction in incidence of other inappropriate medications was also observed; however, statistical significance was not reached. The use of computerized clinical decision support can be a powerful tool in reducing or ameliorating medication errors, and further study will be required to determine the most appropriate and effective implementation strategies.

Keywords

anesthetics, pain management, information systems and technology, medication errors, medication safety

Background

The use of epidural anesthesia has been shown to improve morbidity and mortality outcomes in the postoperative setting.^{1,2} However, despite the advantages to epidural analgesia, there are several complications that health care providers must be cognizant of when initiating, maintaining, and discontinuing epidural therapy.

Complications can be grouped into 2 main categories: complications related to neuraxial administration of medications and complications resulting from bleeding at the epidural catheter site.^{3–7} Complications due to neuraxial administration of opioids, anesthetics, and possibly clonidine can include respiratory depression, hypotension, altered mental status, and somnolence among others and are usually monitored and managed by adjusting doses or rates and in severe cases

using reversal agents such as naloxone.^{3,4} Of bleeding complications with this type of analgesic technique, epidural hematoma is the most concerning as it can result in paraplegia and possibly death.^{5–7} While bleeding risk is very rare with specific risk of intracranial hematoma reported as 0.07 events in 10 000 cases,⁴ the concomitant administration of anti-coagulants, antiplatelets, and thrombolytics has the potential to significantly increase this risk.⁵

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The implementation of computerized physician order entry (CPOE) systems with clinical decision support has been shown to improve correct ordering, improve dosing of high-risk medications, decrease the incidence of adverse events including severe adverse events, increase compliance with policies and order sets, and overall improve prescribing habits.⁸⁻¹¹ In a systematic review by Kaushal et al, multiple studies demonstrated that computerized decision support reduced medication errors and adverse drug events (ADEs), particularly with high-risk medications.⁹

To standardize ordering of epidural anesthesia orders, improve monitoring of patients, and decrease the risk of ADEs including bleeding complications, an electronic ordering module with clinical decision support was implemented in the CPOE at our institution.¹² This module includes recommendations to increase and streamline nursing orders for the monitoring of complications as well as warnings to prescribers about concomitant medications that increase risk of complications. Downstream alerts are displayed to other ordering providers when inappropriate medications are ordered after the original epidural orders were placed.

The primary aim was to evaluate whether the implementation of an electronic epidural module would decrease the incidence of concomitant medication administration identified in the module, as measured by instances of administration of these medications prior to and following implementation of the epidural module at our institution. Secondary aims included assessment of outcomes (respiratory depression, hypotension, naloxone administration, and rapid responses) prior to and after module implementation.

Methods

This study was a retrospective cohort chart review on data existing in the electronic medical record at Vanderbilt University Medical Center, an 1100-bed tertiary care academic medical center in Nashville, Tennessee. This study was approved by the Vanderbilt University Institutional Review Board, receiving exempt status due to minimal risk to patients. Study data were collected and managed using REDCap (Research Electronic Data Capture) electronic data capture tools hosted at Vanderbilt University Medical Center.¹³

All patients receiving at least 1 day of continuous epidural anesthesia therapy with recorded start and stop date, time of therapy, and an evaluable medication administration record were included. Pediatric patients less than 18 years of age and female patients receiving care in the obstetrics, gynecology, or labor and delivery areas were excluded because the electronic ordering module was not implemented in those patient care areas.

Groups were evaluated before and after implementation of a computerized clinical decision support module built within the CPOE system at our institution. The anesthesia

epidural ordering module was initially implemented for standardizing ordering of epidural anesthesia and associated orders. However, during development of the standard orders, the addition of clinical decision support for preventing complications was also incorporated. The result was a comprehensive module for epidural ordering that standardized epidural medication orders, auxiliary orders, nursing orders, lab orders, and addressed concomitant medications that may increase risk of complications, primarily bleeding, excess sedation, and change in hemodynamics (Figure 1). Additionally, if another physician attempted to order a high-risk medication after an epidural was already initiated, a secondary “exit-check” was developed to notify this physician regarding the presence of the epidural infusion and the potential risk involved with their order. This exit-check required the prescriber to fully acknowledge the concomitant ordering of a high-risk medication in patients with an active order for epidural therapy (Figure 2).

Patients were identified retrospectively and divided into 2 cohorts, those receiving an epidural 3 months prior to initiation of the electronic epidural module and those receiving an epidural 3 months following the full implementation of the module including the secondary “exit-check” notification. The time periods were not concurrent as full implementation did not occur at 1 time. Therefore, there was a preimplementation data collection for the 3 months prior to initial implementation and then a period where implementation and testing of the system occurred. The postimplementation data collection occurred after full implementation of the module including the exit-checks when informatics determined that the module was fully and uniformly active in the CPOE system.

Data on patient disposition; reason for therapy; medications used in the epidural anesthesia preparation; medications administered prior to, during, and following therapy; and any reported complications secondary to the epidural as reported by the Acute Pain Service were collected by manual chart review for all patients. Data were analyzed based on each epidural event, not per patient, because some patients received more than 1 epidural at various times during their hospitalization or over multiple hospitalizations.

The primary outcome of inappropriate medication administration was determined by application of the American Society of Regional Anesthesia (ASRA) Guidelines on Regional Anesthesia in the Patient Receiving Antithrombotic or Thrombolytic Therapy⁵ (Table 1). In addition, administration of promethazine was considered inappropriate by the Department of Anesthesiology Acute Pain Service due to its potent sedating effects.⁸ The decision support module screened for medication administration at the time of epidural order placement as well as orders placed in the hospital prior to the procedure, but due to limitations in the system, there was no screening for medications ordered or administered prior to admission to the hospital. The module also screened

HEO Popup

ZTESTHMM , PSTEST Age 40 years Gender male Actual Weight 70 kg Nursing Unit VCH3 OR01

Anesthesia Pain Service - Epidural Infusion Orders

Current Allergy List in HEO/WizOrder: No Allergies Found.

Lab Values: INR, PT, PTT, PLT, SCr, CrCl

Active Opioids on Profile: enoxaparin for dvt prophylaxis 30mg subcut q12h »Apr 1 10:00...

☐ <-- Check Here if Allergy List, Lab Values, Active Profile Opioid and AntiCoagulant lists have been reviewed

APS Resident Beeper #835-5701

Catheter Location: [Dropdown]

Pump Type: Epidural Pump

Medication: Bupivacaine 0.1% (1/10%)

Narcotic Additive: None

Other Additive: None

Diluent: Normal Saline 250 mL

Basal Infusion Rate: none mL/hr

Demand Dose (Balut): none mL

Demand Interval: none minutes

Lockout: mL in one hour

Continue for: UNTIL DISCONTINUED

Comments:

Start Date/Time: 04 / 14 / 11 1700

☐ Order Epidural despite an active LMW Heparin order on profile

☐ Order Epidural and Discontinue active

RASS Undefined. You will be prompted to enter a RASS upon order submission

☒ Epidural Pump to be supplied by pharmacy with initial bag

☒ PRN Medications (select all) Absent checkbox indicates order on profile

☒ Nalbuphine (Nubain) 5 mg IV q4h pm pruritis

☒ Ondansetron (Zofran) 4 mg IV q8h pm nausea

☒ Additional PRN Medications (select individually) Absent checkbox indicates order on profile

☐ Normal Saline 250 ml IV bolus ONCE pm for SBP less than 80 or MAP less than 50

☐ Ketorolac (Toradol) 30 mg IV q8h pm pain

☐ Diphenhydramine (Benadryl) 12.5 mg IV q8h pm itching

☐ Naloxone 0.1-0.4 mg IV pm respiratory distress or narcotic overdose

☐ Standby Medications misc as dir - "Have available for APS: bupivacaine 0.25% vial; ephedrine 50 mg amp; hydromorphone 1 mg amp; lidocaine 2% (preservative free) 10 ml; lidocaine 2% w/ epi (preservative free) 20 ml; phenylephrine 10 mg vial"

☒ Vital Signs (select all) Absent checkbox indicates order on profile

☒ Monitor Respiratory Rate

☒ Monitor sedation according to the sedation scale and motor function according to Bromage scale

☒ Monitor sedation scale and motor function q4h and before ambulating. Do not ambulate if sedation or motor function not WNL. Notify APS immediately if motor function abnormal.

☒ Monitor Pain Scale (0-10) q4h and document

☒ Continue to monitor motor function q4h for 24h after removal of epidural catheter - Notify APS immediately for changes

☒ Monitor epidural site qshift for erythema

☒ In & out cath q8h pm for bladder distention & notify primary service

☒ Nursing Orders (select all) Absent checkbox indicates order on profile

Back Home Print Close

Figure 1. Initial epidural anesthesia order screen.

prospectively while the epidural orders were in place with the exit-check component of the module.

Secondary outcomes included instances of ADEs, including respiratory depression (respiratory rate <8 breaths per minute), hypotension (systolic blood pressure <80 mm Hg), administration of reversal-dose naloxone, and rapid response team or cardiopulmonary arrest codes called while on epidural therapy. Secondary outcomes were collected to assess for complications of concomitant use of promethazine, known to cause respiratory depression and/or hypotension, and neuraxial opioids.

Statistical Analysis

The primary and secondary outcomes were reduced to dichotomous data and were analyzed using chi-square tests. Baseline characteristics and other data were analyzed by Student *t* tests or descriptive statistics where appropriate. Statistical significance was defined as $P < .05$. Due to the nature of the study and primary outcome, the authors planned a post hoc power analysis rather than a sample size calculation as effect size estimates are not clear in the

literature. Statistical analyses were completed by the study authors utilizing JMP 8.0 software (SAS Institute, Cary, NC.)

Results

In the 3-month period prior to implementation of the electronic epidural ordering, 304 cases of epidural administration were identified. Of identified cases, 203 were included in the analysis, with 101 being excluded due to cases occurring in patient care units where the module was not implemented or there was inadequate information in the chart to evaluate outcomes for the case. In the 3-month period following implementation of the epidural module with the exit-checks, 173 cases of continuous epidural administration met inclusion criteria and were included in the analysis.

Patient characteristics are reported in Table 2. There were no significant differences between the 2 groups in terms of patient characteristics. Each study group had patients with a similar mean age, male to female ratio, and average duration of epidural therapy. The indications for epidural therapy are described in Table 3.

CAUTION: Bleeding Risk

Patient has an Active Epidural Infusion : Review and Respond to medication alert(s) below
If medication below is ordered, Anesthesia Pain Service will be notified.

Current Active Epidural Infusion Order aps-epidural infusion; epidural -diluent: ns 250 ml -basal rate: 8 ml/hr -demand rate: 3ml q15 min -ingredient: bupivacaine 0.1% (33.3 ml bupi 0.75%)* -comments: lockout=20 ml/hr;cath:t 6-7 »Mar 21 17:00...

Current Allergy List in HED/WizOrder	Lab Values	Active Opioids on Profile
* allergy to drug: egg - intolerance overexaggeration »Feb 21 00:00:00 2011...	INR	Active AntiCoagulants on Profile
* allergy: nkda »Sep 25 14:52:00 2007...	PT	warfarin: 4mg po qbedtime "target inr 2-3" »Mar 4 22:00...
	PTT	clopidogrel: plavix 75mg po qday 10 »Mar 31 10:00...
	PLT	clopidogrel loading dose 600mg po x1
	SCr	clopidogrel loading dose 600mg po x1 »Mar 30 10:25
	CrCl	enoxaparin inj: lovenox 110mg subcut q12h »Mar 8 22:00...

APS Resident Beeper # 835-5701

☒ Order clopidogrel despite active epidural infusion on profile
☐ Discontinue all clopidogrel order(s) on profile

Submit Order

Back Home Print

Figure 2. Exit-check screen.

Table 1. Inappropriate or Contraindicated Medications.

Medication	Time to stop prior to placement of epidural
Warfarin	5 days
Low-molecular-weight heparin	
Treatment	24 hours
Prophylaxis	12 hours
Unfractionated heparin	
Intravenous	4 hours
Subcutaneous	2 hours
Ticlopidine	14 days
Clopidogrel	7 days
Glycoprotein IIb/IIIa inhibitors	4 weeks
Thrombolytics	10 days
Other anticoagulants	Avoid ^a

^aGuidelines recommend avoiding but no specific time frames given. Timings based on the American Society of Regional Anesthesia (ASRA) Guidelines on Regional Anesthesia in the Patient Receiving Antithrombotic or Thrombolytic Therapy.⁵

There were more patients receiving epidural therapy for gastrointestinal/genitourinary ($P = .015$) in the postimplementation group as compared with the preimplementation group and more cardiovascular surgery cases in the preimplementation group than the postimplementation group ($P = .003$) although the incidence of this type of procedure was very small.

The primary and secondary end points are reported in Table 4. For the primary end point of inappropriate medication administration, there was a trend toward a statistically significant difference between groups ($P = .05$) with a reduction in the postimplementation group. When looking at differences between groups by medication, there was a statistically significant difference between groups in regard to enoxaparin administration (3.9% of cases preimplementation and 0% postimplementation, $P = .002$). This is a particularly important finding in that the use of a fully-implemented CPOE epidural module with exit-checks was able to eliminate inappropriate anticoagulation use in our study group. There was no statistically significant difference found for the secondary end points of respiratory depression ($P = .97$), hypotensive events ($P = .49$), and naloxone reversal-dose administration ($P = .34$) between groups. There were fewer instances of rapid responses in the postimplementation group than the preimplementation group; however, this difference was not statistically significant ($P = .08$).

Discussion

In this retrospective study examining the effectiveness of a computerized clinical decision support module implemented into the CPOE system at an academic medical center, we observed a nonsignificant reduction in inappropriate medication administration before and after full module implementation. Of note, a significant difference in the use of enoxaparin was

Table 2. Baseline Characteristics.

	Preimplementation (n = 203)	Postimplementation (n = 173)	P
Male, % (n)	58 (118)	53 (92)	.35
Age	54.8 ± 15.4	57.4 ± 14.1	.09
Height (cm)	172.2 ± 10.3	170.4 ± 10.3	.09
Weight (kg)	80.8 ± 20.9	81.8 ± 20.1	.63
Duration of therapy (d)	4.4 ± 1.2	4.5 ± 1.2	.42

Note. Data presented as mean ± SD.

Table 3. Indication for Epidural Therapy.

	Preimplementation (n = 203)	Postimplementation (n = 173)	P
Burn	4 (8)	1 (2)	.08
Cardiovascular surgery	4 (8)	0 (0)	.003
GI or GU surgery	25 (50)	36 (63)	.02
Oncology surgery	1 (1)	2 (3)	.24
Orthopedic surgery	4 (9)	3 (6)	.62
Thoracic surgery	38 (78)	31 (54)	.13
Trauma	21 (42)	25 (44)	.29
Other	3 (7)	1 (2)	.13

Note. Data presented as % (n). GI = gastrointestinal; GU = genitourinary.

Table 4. Primary and Secondary End Points.

	Preimplementation (n = 203)	Postimplementation (n = 173)	P
Improper medication administered	13.3 (27)	6.3 (11)	.054
Enoxaparin	3.9 (8)	0 (0)	.002
Promethazine	9.4 (19)	6.3 (11)	.27
Respiratory depression	3.9 (8)	4.0 (7)	.97
Hypotensive events	23.6 (48)	20.7 (36)	.49
Naloxone administered	2.5 (5)	1.2 (2)	.34
Rapid responses	3.9 (8)	1.2 (2)	.08

Note. Data presented as % (n). Medications not listed did not have any instances of inappropriate administration.

observed when examining the primary end point by medication. This difference was of particular clinical importance because there were no instances of improper anticoagulant administration in the postimplementation group, while inappropriate enoxaparin use represented about 30% of total inappropriate medication administrations in the preimplementation group. Although the total number of inappropriate medication administrations was small, risk of complications with anticoagulants and epidural use can be particularly significant. This study was completed prior to the approval of many of the direct oral anticoagulants (apixaban, edoxaban, and rivaroxaban), and therefore these medications were not addressed with the epidural module. There is opportunity for addition of these medications to the module as prescribers may not be familiar with these medication names and their mechanisms as anticoagulants.

When implementing clinical decision support, whether electronic or manual, it is essential that the intervention first

be evaluated for feasibility of use and that the timing of the intervention is well understood. For a tool to be effective, it must be appropriately utilized and there must be acceptance from prescribers. In the case of our clinical decision support tool, a few hypotheses have been formulated for why the module demonstrated a trend toward improved outcomes, yet our results did not show a significantly decreased risk of inappropriate medication administration and decreased complications. When epidural therapy is initiated at our institution, it most often occurs in the operating room prior to an order for epidural therapy being placed to the pharmacy. This results in catheter insertion prior to the provider being exposed to the ordering module and could result in patients being on inappropriate high-risk medications without the provider's knowledge. As the epidural ordering module gains acceptance among providers performing epidurals, they will presumably utilize it prior to catheter insertion. In addition, the ordering module was originally designed as an

up-front ordering module only and did not flag high-risk medications for the entirety of epidural therapy. Therefore, an opportunity existed for a different provider who was unfamiliar with the restrictions associated with epidural management to order one of the inappropriate medications without any warning or instruction. To address this concern, the informatics team developed a secondary “exit-check” to notify other prescribers of the presence of an epidural infusion if they tried to order a high-risk medication after an epidural was placed. This exit-check required the prescriber to fully acknowledge the concomitant ordering of a high-risk medication in patients with an active order for epidural therapy.

With the full implementation of the decision support module, our postimplementation group showed a decrease, although not statistically significant, in the overall instances of inappropriate medication administration. Of note, the postimplementation group showed an elimination of improper enoxaparin administered versus the preimplementation group.

Limitations of this study are that it was a retrospective chart review at a single academic medical center over a very short period of time. Our study was underpowered based on a post hoc power analysis utilizing sample sizes in each group and the effect size found in the primary outcome (and assuming $\alpha = 0.05$). Although the study did not have adequate power on a post hoc analysis, our data did show a significant reduction in inappropriate enoxaparin prescribing. The study authors felt that identifying a period of time around the implementation of the epidural module would be most beneficial to control for confounders and changes in practice not relating to the research question. This likely limited the number of patients to be evaluated and resulted in not meeting power. In addition, limitations to the module itself and the inability to screen for medications administered prior to admission could have affected the results of the study. The type and dose of epidural administration was also not collected and could have affected the secondary outcomes rates. One of the major challenges with high-risk medications is the difficulty in screening for these medications prior to admission. Some computerized medication records now incorporate a home medication list in the screening tool; however, this assumes an accurate medication reconciliation was obtained, which is a difficult assumption in many practice settings. However, the results seen in this study can be clinically applicable given the nature of the outcomes and reduction in medication error risk. The most significant limitation of this study was the acceptance and functionality of the ordering module itself, and further examination of its functionality is needed to optimize this tool.

Conclusion

In conclusion, a computerized clinical decision support tool for continuous regional epidural anesthesia therapy that was incorporated into the CPOE system at Vanderbilt University

Medical Center was not associated with a significant difference in the overall incidence of inappropriate medication administration or therapy-related complications, but was associated with the reduction in the administration of enoxaparin and eliminated all inappropriate anticoagulant administration. There was also a nonsignificant reduction in the postimplementation group in rapid response events, naloxone administration, and improper medication use overall. Further study would be required with a larger sample size to determine the significant differences of these rare events. While there are many possible reasons for these findings, the results underscore the importance of proper use of clinical decision support with additional research about how such tools are utilized in practice. This study also shows the importance of testing interventions such as decision support to ensure that efforts to implement such tools are resulting in better patient care and positive outcomes. Future study on high-risk medication screening in the outpatient setting prior to admission would be beneficial as computerized decision support and synchronization of medical records systems continue to improve.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

References

1. Rodgers A, Walker N, Schug S, et al. Reduction of postoperative mortality and morbidity with epidural or spinal anaesthesia: results from overview of randomised trials. *BMJ*. 2000;321:1493.
2. Wu CL, Hurley RW, Anderson GF, Herbert R, Rowlingson AJ, Fleisher LA. Effect of postoperative epidural analgesia on morbidity and mortality following surgery in Medicare patients. *Reg Anesth Pain Med*. 2004;29:525-533.
3. Horlocker TT, Burton AW, Connis RT, et al. Practice Guidelines for the Prevention, Detection, and Management of Respiratory Depression Associated with Neuraxial Opioid Administration: an updated report by the American Society of Anesthesiologists Task Force on neuraxial opioids. *Anesthesiology*. 2009;110(2):218-230.
4. Brull R, McCartney CJ, Chan VW, et al. Neurological complications after regional anesthesia: contemporary estimates of risk. *Anesth Analg*. 2007;104(4):965-974.
5. Horlocker TT, Wedel DJ, Rowlingson JC, Enneking FK. Regional anesthesia in the patient receiving antithrombotic or thrombolytic therapy: American Society of Regional Anesthesia and Pain Medicine evidence-based guidelines (third edition). *Reg Anesth Pain Med*. 2010;35:64-101.
6. Gogarten W. The influence of new antithrombotic drugs on regional anesthesia. *Curr Opin Anaesthesiol*. 2006;19:545-550.
7. Gogarten W, Vandermeulen E, Van Aken H, et al. Regional anaesthesia and antithrombotic agents: recommendations of

- the European Society of Anaesthesiology. *Eur J Anaesthesiol*. 2010;27:999-1015.
8. Lucchetti G, Lucchetti ALG, Pires SL, Gorzoni ML. Beers-Fick criteria and drugs available through the Farmácia Dose Certa program. *Sao Paulo Med J*. 2011;129:17-22.
 9. Kaushal R, Shojania KG, Bates DW. Effects of computerized order entry and clinical decision support systems on medication safety: a systematic review. *Arch Intern Med*. 2003;163:1409-1416.
 10. Wolfstadt JJ, Gurwitz JH, Field TS, et al. The effect of computerized physician order entry with clinical decision support on the rates of adverse drug events: a systematic review. *J Gen Intern Med*. 2008;23(4):451-458.
 11. Shamliyan TA, Duval S, Du J, Kane RL. Just what the doctor ordered. Review of the evidence of the impact of computerized physician order entry system on medication errors. *Health Serv Res*. 2008;43:32-53.
 12. Gupta RK. Using an electronic clinical decision support system to reduce the risk of epidural hematoma. *Am J Ther*. 2014;21(5):327-330.
 13. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform*. 2009;42(2):377-381.