Impact of thoracic epidural catheter threading distance on analgesia during the first 24 hours following thoracotomy: a randomized controlled trial

Impact de la distance d'insertion du cathéter péri-dural thoracique sur l'analgésie au cours des 24 premières heures suivant une thoracotomie: une étude randomisée contrôlée

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Abstract

Purpose The purpose of this prospective randomized controlled trial was to determine the impact of thoracic epidural catheter threading distance on analgesia quality after thoracotomy.

Methods We randomly assigned 120 elective thoracotomy patients to a thoracic epidural catheter threading distance of 3, 5, or 7 cm (groups 3CM, 5CM, and 7CM, respectively). Epidural bupivacaine 0.1% with fentanyl $2 \mu\text{g}\cdot\text{mL}^{-1}$ was administered according to a standardized protocol. Epidural analgesia quality was assessed at 60 min and 24 hr postoperatively for four measures: incidence of non-functioning epidurals; numerical rating score (NRS) < 4 at rest, while coughing, and during wound palpation; cold perception at the wound site; and cumulative dose of analgesic medication used. Our primary hypothesis was that, compared to threading distances of 3 and 5 cm, a threading distance of 7 cm was not inferior at providing an NRS < 4 while coughing at 60 min postoperatively, with a non-inferiority margin of 25% (absolute value) being significant.

Results The incidence of NRS < 4 while coughing at 60 min was 74% (29/39) in group 7CM compared with 68% (54/80) in the combined 3CM and 5CM groups (absolute

difference 7%; 95% confidence interval -11 to 23 ; $P = 0.29$). At both 60 min and 24 hr, differences between groups were similar regarding the number of non-functioning epidurals, NRS < 4 , and suppressed cold sensation. Analgesic doses were similar in the three groups.

Conclusions This study found that a thoracic epidural catheter threading distance of 7 cm in the epidural space was not inferior to distances of 3 cm and 5 cm with respect to pain scores at 60 min postoperatively. This study was not powered to examine differences that could have clinical significance that were less than our a priori 25% non-inferiority margin.

Résumé

Objectif L'objectif de cette étude prospective randomisée contrôlée était de déterminer l'impact de la distance d'insertion du cathéter péri-dural thoracique sur la qualité de l'analgésie après une thoracotomie.

Méthodes Nous avons randomisé 120 patients devant subir une thoracotomie programmée à une distance de 3, 5 ou 7 cm d'insertion du cathéter péri-dural thoracique (respectivement, groupes 3CM, 5CM et 7CM). De la bupivacaine 0,1 % avec du fentanyl $2 \mu\text{g}\cdot\text{mL}^{-1}$ a été administrée via le cathéter péri-dural selon un protocole standardisé. La qualité de l'analgésie péri-durale a été analysée selon quatre critères à 60 minutes et 24 heures: incidence des péri-durales non fonctionnelles; score de cotation numérique (NRS - numerical rating score) < 4 au repos, à la toux et à la palpation de la plaie; perception du froid au niveau de la plaie; et dose cumulée d'analgésique utilisé. Notre hypothèse principale était que, comparativement aux distances d'insertion de 3 cm et

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5 cm, une distance d'insertion de 7 cm n'était pas inférieure pour l'obtention d'un score NRS < 4 à la toux, 60 minutes postopératoires, en considérant une marge de non-infériorité de 25 % (valeur absolue) comme significative.

Résultats L'incidence des scores NRS < 4 à la toux à 60 minutes a été de 74 % (29/39) dans le groupe 7CM comparativement à 68 % (54/80) dans les groupes combinés 3CM et 5CM (différence absolue 7 %; intervalle de confiance à 95 %: 11 à 23; $P = 0,29$). Les différences entre les groupes ont été semblables à 60 minutes et 24 heures pour ce qui concernait le nombre de péridurales non fonctionnelles, de scores NRS < 4 et la suppression de la sensation de froid. Les doses d'analgésiques ont été semblables dans les trois groupes.

Conclusions Cette étude a montré qu'une distance d'insertion de cathéter péridural de 7 cm n'était pas inférieure aux distances de 3 cm et 5 cm pour ce qui concerne les scores de douleur à 60 minutes postopératoires. Cette étude n'avait pas la puissance nécessaire pour analyser les différences susceptibles d'être cliniquement significatives et qui seraient inférieures à notre marge prédéfinie de non-infériorité de 25 %.

Thoracotomy is associated with significant postoperative pain. Local anesthetics with or without opioids infused via a thoracic epidural catheter are regarded as the analgesic gold standard for this type of surgery.¹⁻⁴ Maximizing the thoracic epidural success rate is important because thoracic epidural analgesia has been shown to significantly reduce the incidence of respiratory complications,¹⁻⁴ which are the major cause of morbidity and mortality after thoracic surgery.⁵ Thoracic epidural catheter placement is sometimes challenging, however, which partly explains its high failure rate of up to 15%.^{1,6} Suboptimal placement of the catheter in the epidural space may account for some failed epidurals. Radiographic studies having demonstrated that catheters can behave unpredictably when threaded into the epidural space, often forming a terminal loop, coiling at the insertion site, or migrating out through an intervertebral foramen.^{7,8}

The optimal threading distance of a thoracic epidural catheter has not been previously studied. Catheters threaded further into the epidural space reduce the chance of dislodgement, especially of the proximal orifice in multiorifice catheters. However, they can migrate out of the epidural space into intervertebral foramina or an epidural vein,^{9,10} thus providing inadequate analgesia during the

immediate postoperative period. Also, catheters have a tendency to move in and out approximately 1 cm even after they have been secured.⁹ Catheters threaded less far might thus migrate over time, with some or all of their orifices being outside the epidural space, and thus be ineffective.¹⁰

A prior study that examined lumbar epidural analgesia in 100 obstetrical patients found that catheters threaded 5 cm into the epidural space, as opposed to 3 cm or 7 cm, yielded the lowest incidence of incomplete analgesia.¹¹ Another study found that dislodgment was more frequent with catheters threaded 2-4 cm, and unilateral anesthesia was associated with greater catheter insertion depths.¹⁰ Alternatively, one study found no significant differences in analgesia when varying the lumbar epidural catheter threading distances.¹² Anatomical differences between the lumbar and thoracic epidural space and important differences in the nature and severity of pain make it difficult to extrapolate these results to thoracotomy patients with mid-thoracic epidural catheters.

No study has specifically addressed the impact of catheter threading distance on thoracic epidurals performed for thoracotomy-related pain relief. Accordingly, the purpose of this prospective randomized controlled trial was to determine the impact of thoracic epidural catheter threading distance on analgesic quality and the incidence of complications after thoracotomy. Our primary hypothesis was that a longer catheter threading distance (7 cm) would not be inferior¹³ to shorter (3 and 5 cm) threading distances at providing analgesia during coughing 60 min after arrival in the postanesthesia care unit (PACU).

Methods

The study protocol was approved in June 2008 by our local ethics committee (Centre hospitalier de l'Université de Montréal (CHUM), Montreal, QC, Canada, CER: 08.071). This prospective randomized study (NCT00754195, clinicaltrials.gov) took place between January 19, 2009 and June 9, 2010. Patients aged ≥ 18 yr presenting for elective thoracic surgery that necessitated thoracotomy were approached by a member of the research team. Exclusion criteria included patient refusal, contraindications to epidural anesthesia (infection at or near the puncture site, sepsis, coagulopathy, hypovolemia, shock, or preexisting neurological deficits that made postoperative evaluation of the epidural block unreliable), pregnancy, previous thoracic spine surgery, allergy to local anesthetics, and inability to communicate adequately secondary to cognitive or linguistic barriers. All patients provided written informed consent.

Patients were randomly assigned to one of three groups based on a computer-generated randomization list: patients

in group 3CM had the epidural catheter threaded 3 cm into the epidural space; patients in group 5CM had the epidural catheter threaded 5 cm into the epidural space; patients in group 7CM had the epidural catheter threaded 7 cm into the epidural space. Patients and the investigators who collected data were blinded to the allocation group. Thoracic epidural catheters were inserted by the attending anesthesiologist, who was verbally informed by the research nurse of the patient's group assignment immediately before performing the epidural.

Prior to induction of general anesthesia, with the patient in the sitting position,¹⁴ thoracic epidurals were placed and standard monitoring was applied.¹⁵ Patients received sedation consisting of intravenous midazolam 0.5–2.0 mg and/or fentanyl 25–100 µg. An 18G Tuohy needle was used, and the epidural space was identified using the loss-of-resistance with saline or air technique via a midline approach at the T6–T7 or T7–T8 interspaces. After the epidural space was located, the distance to the skin was measured using the 1-cm markings on the Tuohy needle. A 20G triple-orifice catheter (Portex Nylon, Smiths Medical ASD, Keene, NH, USA) was then threaded to a distance corresponding to the group assignment through the cranially directed tip of the Tuohy needle. The catheter insertion distance using the 1-cm markings on the skin was noted once the needle was removed (Fig. 1). If persistent paresthesia or excessive resistance was encountered, the anesthesiologist was permitted to substitute a polyurethane catheter (Arrow Flextip, Teleflex Medical, Research Triangle Park, NC, USA) or withdraw the catheter less than 1 cm from the allocated insertion distance. If return of blood was noted with the needle or blood was aspirated from the catheter at the prescribed insertion distance, the needle or catheter was withdrawn. The technique was then repeated one level above or below (according to the attending anesthesiologist's preference) that where the puncture occurred. Next, 5 mL of 1.5% lidocaine with epinephrine 5 µg·mL⁻¹ (1:200,000) was injected via the catheter to exclude intravascular or intrathecal placement, after which the catheter was secured using a transparent dressing (TegadermTM; 3M Health Care, St Paul, MN, USA) and tape (HypafixTM; Smith & Nephew, Australia) tape (Fig. 1).

General anesthesia was induced using a standardized technique (propofol 1–2 mg·kg⁻¹; fentanyl 1–5 µg·kg⁻¹ or sufentanil 0.1–0.5 µg·kg⁻¹ and/or remifentanyl 0.1–2 µg·kg⁻¹; rocuronium 0.6–1.2 mg·kg⁻¹ or succinylcholine 1–2 mg·kg⁻¹) and maintained using desflurane or sevoflurane in O₂/air or 100% O₂. Boluses of intravenous fentanyl (0.25–1.5 µg·kg⁻¹) or intravenous sufentanil (0.025–0.15 µg·kg⁻¹) or intravenous remifentanyl (0.1–1.0 µg·kg⁻¹) were permitted to maintain vital signs within 20% of their baseline. For intraoperative opioid dose

Fig. 1 Epidural catheter with insertion distance markings and the transparent dressing window

comparisons between groups, sufentanil doses were converted to fentanyl equivalents (with a conversion factor of 1:10).

An epidural infusion of bupivacaine 0.1% with fentanyl 2 µg·mL⁻¹ was initiated after anesthesia induction at 0.1 mL·kg⁻¹·hr⁻¹ following positioning in the lateral decubitus position. Apart from the test dose, no other initial boluses were used. To maintain arterial blood pressure and pulse within 20% of the patient's baseline values, the attending anesthesiologist adjusted the epidural infusion between 4 and 16 mL·hr⁻¹. A bolus of 0.1 mL·kg⁻¹ (maximum 7 mL), followed by an increase in the epidural infusion rate of 2 mL·hr⁻¹, was administered if there was an increase in blood pressure and pulse, whereas we decreased the epidural infusion rate by 2 mL·hr⁻¹ in the event of low blood pressure. These changes could be repeated every 30 min if no satisfactory response was observed. The operations were performed by one of five thoracic surgeons at our institution. If a protocol breach occurred before the end of surgery (Fig. 2), the patient was excluded from the study and replaced by another patient from the same group.

At the end of surgery, all patients received acetaminophen 650–1300 mg per rectum¹⁶ and then 975

Fig. 2 CONSORT diagram for the study

mg orally *qid*. Patients were awakened and extubated in the operating room after the surgery. Subcutaneous morphine or hydromorphone was administered in the PACU for patients with postoperative shoulder pain.¹⁶ For postoperative morphine/hydromorphone dose comparisons between groups, the hydromorphone doses were converted to morphine equivalents using a 7:1 ratio.¹⁷

Upon arrival in the PACU, patients were immediately asked to rate their pain at the incision site using a verbal numerical rating score (NRS), where 0 = no pain and 10 = worst imaginable pain.¹⁸ If the NRS was ≥ 4 , they were given an epidural bolus of $0.1 \text{ mL} \cdot \text{kg}^{-1}$ (maximum 7 mL) of bupivacaine 0.1% with fentanyl $2 \mu\text{g} \cdot \text{mL}^{-1}$, and the rate of the epidural infusion was increased by $2 \text{ mL} \cdot \text{hr}^{-1}$. These

boluses and increases in the epidural infusion rate could be repeated every ten minutes until the NRS was < 4 or until a maximum of three boluses and increases in the epidural infusion rate were reached.

After discharge from the PACU, a patient with NRS ≥ 4 was managed by an intermediate care unit nurse blinded to the allocation group using a protocol similar to that used in the PACU (but only one epidural bolus per hour was permitted). If hypotension occurred, the anesthesiologist responsible for the acute pain service and/or the attending surgeon intervened. The patients were evaluated at 24 hr for the possibility of intravascular migration. In addition, catheter movement was evaluated according to the graduated markings on the skin to verify whether displacement of > 1 cm had occurred.

The study's primary outcome was the incidence of patients with NRS scores < 4 with coughing in group 7CM 60 min after admission to the PACU compared to that for the combined 3CM and 5CM groups. Secondary endpoints included epidural analgesic quality outcomes specifically evaluated per protocol at 60 min and 24 hr after admission to the PACU. They included the rate of non-functional epidurals; differences in pain scores at rest, when coughing, and upon palpation of the incision site; loss of perception to cold at the incision site; and cumulative bupivacaine and postoperative morphine doses.

Patients were deemed to have a non-functional epidural if, after three boluses and increases in epidural perfusion rates in the PACU, they still had an NRS ≥ 4 and/or no detectable loss of sensitivity to cold. For patients who met these criteria, the epidural catheter was removed, and the attending anesthesiologist initiated another analgesic modality. All patients with non-functioning epidurals at the time of the evaluations were considered to have NRS ≥ 4 .

A member of the research team who was blinded to patient group allocation did all of the NRS pain assessments while the patient was coughing forcefully (i.e., as though trying to expel pulmonary secretions) and upon palpation of three standardized areas (posterior, midline, anterior) along the incision (Fig. 3). Palpation data were classified according to whether an NRS score was ≥ 4 at any of the sites (inadequate pain control), only one or two sites (partial pain control), or all three sites (satisfactory pain control).

Loss of cold perception was evaluated with ice at six standardized areas (posterosuperior, posteroinferior, middle-superior, middle-inferior, anterosuperior, anteroinferior) around the incision site (Fig. 3). If the ice felt less cold than a reference point unaffected by the epidural block, the area being tested was considered blocked. Cold perception data were classified according to whether none of the six areas was blocked (inadequate sensory block), some areas were blocked (partial sensory block), or the block

Fig. 3 Areas around the incision where loss of cold perception and pain upon palpation were tested

diminished cold perception at all six test areas (satisfactory sensory block).

Statistical analysis

The sample size was calculated assuming that the longer (7 cm) threading distance was not inferior to a shorter distance (3 or 5 cm) at providing a pain NRS < 4 while coughing 60 min postoperatively. We used a non-inferiority margin of 25% (absolute value), an expected proportion of successful analgesia of 85%^{1,6} in the test and control groups, a power of 80%, and a one-sided confidence level of 0.05 in our calculations. As we planned *a priori* to pool the 3CM and 5CM groups, we used a 2:1 ratio of groups in the calculations, resulting in group sizes of 76 in the combined 3CM/5CM group and 38 in the 7CM group. These values were rounded up to 80 and 40, respectively.

All data were analyzed according to the assigned study group and in an intention-to-treat manner. Continuous perioperative data were analyzed using Student's *t* test or one-way analysis of variance. Categorical data, including the primary outcome, were analyzed by creating 2×2 (for the primary outcome using the pooled groups or comparisons between individual groups), 2×3 , or 3×3 (for comparisons between all unpooled groups) contingency tables and using Fisher's exact test. The 95% confidence interval (CI) of the differences between proportions was calculated using Statkey version 0.3.12 performing a 10,000-sample basic bootstrap method.¹⁹ Data were stored in a Microsoft Excel database and analyzed using IBM SPSS Statistics version 21 (Armonk, NY, USA).

Results

The CONSORT diagram for the study appears in Fig. 2. Table 1 shows the patients' demographic and epidural technique data. Aspiration of blood was noted in seven cases: six while performing the epidural technique and one (in group 7CM) in the PACU. One patient in group 5CM had the catheter withdrawn < 1 cm from the prescribed insertion distance because of persistent paresthesia when the catheter was 5 cm into the epidural space. Intraoperative fentanyl equivalent doses were similar in groups 3CM (246 ± 110 µg), 5CM (256 ± 103 µg), and 7CM (260 ± 120 µg). The five surgeons were evenly distributed among the groups.

The primary outcome was assessed in 119 of 120 patients (Tables 2 and 3). One patient in the 7CM group remained intubated at the 60-min evaluation point but was able to communicate that his epidural was functional. There were no quantitative data for him, however. The incidence of NRS < 4 on coughing at 60 min was 74% (29/39) in group 7CM compared with 68% (54/80) in the combined 3CM and 5CM groups (absolute difference 7%; 95% CI -11 to 23; $P = 0.293$).

Table 2 shows the results, by allocation group, of the 60-min evaluation of the four epidural quality measurements (secondary end points). Table 3 gives details of the differences between groups at 60 min for the non-functional epidurals, NRS < 4 at rest, and NRS < 4 while coughing.

Table 4 shows the results of the 24-hr evaluation, by allocation group, of the four epidural quality measurements. The NRS while coughing and the other epidural quality measurements were again similar among the groups. Table 5 gives details of the differences among the groups at 24 hr for non-functional epidurals and NRS < 4 at rest and while coughing.

Discussion

This study is a first attempt to provide data on the impact of the catheter threading distance on the quality of thoracic epidural analgesia. As was the case for studies examining lumbar epidural analgesia,¹¹ our study was designed to determine if longer catheter insertion distances were not inferior to shorter distances. It was not powered, however, to demonstrate superiority of one technique over another. Differences between groups did not reach statistical significance for the primary end point or any of the other measures of epidural analgesia quality at either 60 min or 24 hr after surgery, thus confirming non-inferiority. Indeed, 60 min after arrival in the PACU, no significantly inferior analgesia was observed while coughing with catheters threaded 7 cm in the epidural space compared with insertion distances of 3 or 5 cm.

Group 7CM was isolated in this comparison to determine whether catheters threaded farther into the patient would migrate outside the epidural space more

Table 1 Patient demographics and epidural technique data

Parameter	3CM <i>n</i> = 40	5CM <i>n</i> = 40	7CM <i>n</i> = 40
Age (yr)	63 ± 11	64 ± 9	64 ± 10
Sex, male:female (<i>n</i>)	24:16	17:23	23:17
Weight (kg)	76 ± 20	75 ± 17	75 ± 16
Height (m)	1.69 (0.11)	1.65 (0.11)	1.66 (0.10)
Intraoperative opioids			
Fentanyl equivalents (µg)	246 (110)	256 (103)	260 (120)
Remifentanyl (µg) †	40 (0-100)	50 (0-100)	55 (0-100)
Level of epidural			
T4 or above	0	0	1
T5-T8	40	38	38
T9 or below	0	2	1
Aspiration of blood through the needle/catheter (<i>n</i>)	1/3	0/2	0/1
Catheter distance at skin (cm)	10 (2)	12 (2)	15 (2)
Catheter movement after 24 hr			
0-1 cm	30	34	32
> 1 cm	8	4	4

Values expressed as means ± SD

†Non-normally distributed values are expressed as median (interquartile range)

Table 2 Epidural analgesic quality evaluations at 60 min postoperatively

Allocation group:	3CM	5CM	7CM	<i>P</i>
Non-functional epidural	2/40 (5%)	1/40 (3%)	4/40 (10%)	0.500
NRS at rest < 4	32/40 (80%)	31/40 (78%)	33/39 (85%)	0.771
NRS at cough < 4	28/40 (70%)	26/40 (65%)	29/39 (74%)	0.681
Pain on palpation:				
NRS ≥ 4, 3 sites	4 (10%)	6 (15%)	4 (10%)	0.763
NRS < 4, 1-2 sites	4 (10%)	6 (15%)	3 (8%)	
NRS < 4 3 sites	32 (80%)	28 (70%)	32 (82%)	
Reduction of cold perception:				
none	2 (5%)	1 (3%)	4 (10%)	0.307
some sites	6 (15%)	7 (18%)	2 (5%)	
all sites	32 (80%)	32 (80%)	33 (85%)	
Analgesic medication totals:				
Bupivacaine (mg)	40 (11)	43 (19)	40 (16)	0.675
Postoperative morphine equivalent (mg)	8 (6)	9 (5)	9 (6)	0.403

P values for two-sided Fisher's exact test on the 3 × 2 or 3 × 3 contingency tables representing the data or one-way analysis of variance

NRS = numerical rating score (0-10) for pain

Table 3 Comparisons between groups for epidural functionality and pain scores at 60 min postoperatively

Allocation group comparison	7CM vs 3CM+5CM	5CM vs 3CM	7CM vs 3CM	7CM vs 5CM
Non-functional epidural at 60 min	6% (−4 to 18) <i>P</i> = 0.220	−3% (−10 to 5) <i>P</i> = 1.0	5% (−5 to 18) <i>P</i> = 0.675	8% (−2.5 to 20) <i>P</i> = 0.359
NRS at rest < 4 at 60 min	7% (−9 to 20) <i>P</i> = 0.622	−3% (−20 to 15) <i>P</i> = 0.793	5% (−13 to 22) <i>P</i> = 0.770	7% (−11 to 25) <i>P</i> = 0.568
NRS at cough < 4 at 60 min	7% (−11 to 23) <i>P</i> = 0.293 (1 sided)	−5% (−25 to 15) <i>P</i> = 0.812	4% (−16 to 25) <i>P</i> = 0.803	9% (−11 to 30) <i>P</i> = 0.333

Values represent absolute difference between groups, with 95% confidence intervals

P values for two-sided Fisher's exact test except where noted

NRS = numerical rating score (0-10) for pain

often and thus provide inferior analgesia.^{10,11,20} Although our primary outcome had confidence intervals overlapping zero, analysis of the incidence of non-functional epidurals showed some potential results similar to those in previous reports. After 60 min, non-functional epidurals were observed 5% (95% CI, −5 to 17.5) and 7.5% (95% CI, −2.5 to 17.5) more often in group 7CM than in group 3CM or 5CM, respectively (Table 3). If these estimates of the difference between groups are accurate, a study with several hundred patients would be necessary for more definitive conclusions regarding clinical differences of this magnitude to be drawn. All non-functional epidurals in group 7CM were diagnosed at 60 min postoperatively (Fig. 2), with no subsequent non-functional epidurals in this group after 24 hr. This finding is in contrast with groups 3CM and 5CM, where non-functional epidurals occurred throughout the observation period (Fig. 2). It is also similar to a previous report in an obstetrical

population.¹⁰ In that study, partial withdrawal of catheters inserted 7 cm into the epidural space may have “rescued” some of the immediate non-functional epidurals by pulling the catheter back into the epidural space, as previously reported for lumbar epidurals.¹⁰

At 24 hr postoperatively, there were no statistically significant differences between groups regarding the proportion of patients with adequate analgesia while coughing. However, two additional catheters did become non-functional over the 24-hr study period in group 3CM vs only one in groups 5CM and 7CM combined (Fig. 2). A short threading distance of 3 cm may allow dislodgement more often over the first 24 hr than longer threading distances because of patient and catheter movement.¹⁰⁻¹² This effect, however, appears to be less pronounced at the thoracic level, although a study with several hundred patients is needed to assess this possibility with a high degree of statistical confidence. Alternatively, assessing

Table 4 Epidural analgesic quality evaluations at 24 hr postoperatively

Allocation group	3CM	5CM	7CM	P
Non-functional epidural	4/40 (10%)	2/40 (5%)	4/40 (10%)	0.769
NRS at rest < 4	34/40 (85%)	38/40 (95%)	36/40 (90%)	0.387
NRS while coughing < 4	24/40 (60%)	27/40 (68%)	27/40 (68%)	0.810
Pain on palpation:				
NRS $\geq$ 4 at 3 sites	6 (15%)	3 (8%)	5 (13%)	0.851
NRS < 4 at 1-2 sites	3 (8%)	5 (13%)	4 (10%)	
NRS < 4 at 3 sites	31 (78%)	32 (80%)	31 (78%)	
Reduction of cold perception				
None	4 (10%)	2 (5%)	4 (10%)	0.190
Some sites	12 (30%)	19 (48%)	9 (23%)	
All sites	24 (60%)	19 (48%)	27 (68%)	
Analgesic medication totals				
Bupivacaine (mg)	288 (77)	290 (82)	277 (73)	0.759
Postoperative morphine eq. (mg)	22 (28)	20 (16)	25 (21)	0.608

P values for two-sided Fisher's exact test on the 3×2 or 3×3 contingency tables representing the data or one-way analysis of variance. NRS = numerical rating score (0-10) for pain

Table 5 Comparisons between groups for epidural functionality and pain scores at 24 hr postoperatively

Allocation group comparison	5CM vs 3CM	7CM vs 3CM	5CM vs 7CM
Non-functional epidural at 24 hr	-5% (-18 to 5) $P = 0.675$	0 (-13 to 13) $P = 1.000$	5% (-8 to 18) $P = 0.438$
NRS at rest < 4 at 24 hr	10% (-3 to 22) $P = 0.263$	5% (-10 to 20) $P = 0.737$	-5% (-18 to 5) $P = 0.737$
NRS while coughing < 4 at 24 hr	7.5% (-13 to 28) $P = 0.642$	7.5% (-13 to 28) $P = 0.642$	0 (-20 to 20) $P = 1.000$

Values represent absolute difference between groups, with 95% confidence intervals

P values for two-sided Fisher's exact test

NRS = numerical rating score (0-10) for pain

patients over a longer period of time (e.g., 48, 72, or 96 hr) might reveal greater differences between groups regarding the rate of non-functional epidurals.

Aspiration of blood through an epidural catheter occurred in 5% (6/120) of the epidurals but was not associated with any particular catheter insertion distance. Indeed, large meta-analyses involving more than 10,000 patients have been necessary to establish this relation with lumbar epidurals.²¹ Other strategies for reducing catheter venipuncture - such as saline injection through the epidural needle²¹ or systematic use of wire-embedded polyurethane catheters²¹ - could also play a role in reducing the incidence of bloody thoracic taps.

Several previous studies examined the impact of catheter insertion distance on analgesia in lumbar epidurals.¹⁰⁻¹² Beilin *et al.* studied 100 parturients¹¹ and found a significantly higher proportion of patients with incomplete analgesia in the 7- and 3-cm groups than in the 5-cm group, a higher incidence of vascular puncture in the

7-cm group, and one catheter dislodgement in the 3-cm group. D'Angelo *et al.* studied 800 parturients and found more unilateral blocks in the 4-, 6-, and 8-cm groups vs the 2-cm group, more intravenous cannulations in their 8-cm group, and a higher incidence of catheters that became dislodged in their 2- and 4-cm groups. Afshan *et al.*, in a study of 102 women undergoing hysterectomy, recorded similar pain scores in their 3-, 5-, and 7-cm groups, with one lateralized block in the 7-cm group and one catheter dislodgement in the 3-cm group. Major differences between these studies and the present report (in addition to the level of epidural catheter placement with associated differences in spinal canal diameter, venous anatomy, and pressure in the sitting position) include the cause of pain (thoracotomy vs hysterectomy or labour), the presence of males in our population, additional patient manipulation related to the lateral decubitus required for thoracotomy, and the methods used to evaluate epidural analgesia quality,²² including the reporting of pain scores at rest,

after wound palpation, and during a functional test (coughing). Although in use clinically at our institution, palpation has not previously been reported as a method for assessing thoracotomy pain in humans.²³ Palpation scores appeared to be closely related to other measured pain scores, although this study was not specifically designed to examine this relation.

In addition to the methodological differences and limitations already stated, several others may have contributed to differences between the results observed in the present study and previous reports. In contrast to lumbar epidural analgesia studies during labour, in the present study analgesia could be optimized over a longer period of time with boluses of local anesthetics delivered according to a standardized protocol, in addition to the local anesthetic solution infused intraoperatively, resulting in administration of large volumes of local anesthetic [41 (SD) 15 mL total] before the first evaluation 60 min after arrival in the PACU. This type of management may have improved the spread of the anesthetic and thus “normalized” the quality of analgesia of sub-optimally placed catheters. In support of this hypothesis, no difference in analgesia between epidural catheter insertion distances was seen postoperatively after hysterectomy¹² when patients were managed with infusions stated in their protocol, similar to that in the present study. Anatomical differences between the lumbar and thoracic spines and the somatic nature of post-thoracotomy pain, in contrast to the visceral nature of labour pain, may also account for the absence of differences between groups in the present study. Patients in our study also received small amounts of intraoperative, short-acting opioids as well as postoperative morphine in the recovery room and on the ward for post-thoracotomy shoulder pain unrelated to the incision. This added analgesia may have contributed to pain relief while coughing and may have reduced the effect of the catheter threading distance. Difficulty in differentiating postoperative shoulder pain (which may be severe¹⁶ and does not respond to epidural analgesia) from incisional pain may also have reduced differences in the primary outcome. The challenging choice of good pain control (NRS < 4) while coughing as the primary outcome resulted in relatively low success rates compared with other measures of analgesic quality,²² such as NRS scores at rest, which by 24 hr were < 4 in 90% of patients. However, adequate coughing and breathing are considered essential to prevent postoperative atelectasis and secretion retention, which contribute to respiratory complications.⁴ Other technical factors, such as bevel orientation,²⁴ patient positioning,¹⁴ and the use of imaging,^{25,26} may also play an important role in improving the quality of thoracic epidural analgesia. Finally, our data collection focussed on functional pain control and sensory block at the level of the thoracotomy. Therefore, it was not possible to determine the incidence of other measures of

epidural block quality, such as unilateral blockade or the total number of anesthetized dermatomes.

In conclusion, this study of the effect of catheter insertion distance on the quality of thoracic epidural analgesia did not demonstrate statistically significant differences at either 60 min or 24 hr postoperatively with catheter insertion distances of 3–7 cm. Although the results of this study showed non-inferiority, it was not powered to examine differences having clinical significance that were less than our *a priori* non-inferiority margin of 25%. Based on the present results, however, we would need to study large numbers of patients with thoracic epidurals to assess more conclusively the factors related to non-functioning epidurals, the quality of epidural analgesia over a longer period of time, if catheter withdrawal could rescue a portion of deeply threaded, early non-functional epidurals, or if shorter insertion distances are truly associated with a higher incidence of catheter dislodgement over time.

Author contribution: *Stephan R. Williams* helped design the study, analyze the data, and write the manuscript. He has reviewed the data analysis and approved the final manuscript. *Marc Belliveau* helped design the study and conduct the study. *Veronique Brulotte* helped analyze the data and write the manuscript. *Monique M. Ruel* helped design the study and conduct the study. She is the author responsible for archiving the study files. All authors have seen the original study data and approved the final manuscript.

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