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Fluoroscopy-assisted epidural catheter placement: the effect of dye distribution in preoperative epidurograms on postoperative analgesia

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Abstract

Background: Postoperative epidural analgesia provides superior postoperative analgesia at rest and with activity, compared with systemic opioids. However, the impact of postoperative epidural analgesia on postoperative morbidity and/or mortality remains controversial, because of the sub-optimal reliability of epidural catheters that are placed preoperatively and used for postoperative pain control. The present study used the technique of lumbar epidurography. The study aims to better understand the possible correlation between the fluoroscopic characteristics of epidural catheters following injection of contrast medium and the postoperative functional characteristics regarding analgesia. In this single-arm clinical trial, 70 patients, aged 50 to 75 years old, underwent surgical urological procedures, involving incisions up to T_8 dermatome, under combined general and epidural anesthesia. At the L_2-L_3 level, the epidural space was reached using the loss of resistance technique before general anesthesia was induced. The catheters were threaded upwards for 4–6 cm. Preoperative epidurograms were then done by injecting a 3-ml contrast medium Omnipaque™ (240 mg I/ml) in the epidural catheters. The epidurograms were investigated for the location of the catheter tip in relation to the vertebral body, the extent of dye spread, laterality of dye spread (midline, right, or left), and the presence or absence of dye spread anterior to the spinal cord on the lateral image. The patients were followed postoperatively while epidural analgesia was infused.

Results: Both the postoperative epidural infusion and postoperative visual analog scale (VAS) scores were lower when catheter tips ended at L_1 than when they ended at L_2. As the contrast's vertical spread increases in preoperative epidurograms, the analgesic infusion rate and VAS score decrease, and the number of dermatomes insensitive to cold increases. Epidurographically right-sided catheters showed more dermatomes deficient to cold sensations on the right side, compared with mid-line and left-sided catheters. Restriction of contrast to the posterior epidural space was associated with lower VAS scores and wider anesthesia to cold.

Conclusions: The use of epidurography to study epidural catheters may have the potential advantage of predicting the functionality of catheters and improving the reliability of postoperative epidural analgesia.

Keywords: Lumbar epidural catheters, Epidurography, Postoperative pain

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Background

Administration of medications into the epidural space for postoperative analgesia is a common practice today (Rockford and DeRuter 2009). Epidural infusion of a

solution of local anesthetic and low-dose opioid provides better postoperative analgesia at rest and with movement than systemic opioids. By sparing opioid use and minimizing the incidence of systemic opioid-related side effects, epidural analgesia facilitates earlier mobilization and earlier resumption of oral nutrition, expediting exercise activity, and attenuating loss of body mass (Carli and Baldini 2013).

However, because the standard approach to epidural catheter placement relies on indirect anatomic assessments (palpation, "loss of resistance," and surface measurements of depth), epidural catheters can be nonfunctional or sub-optimal after surgery due to failure to correctly locate or maintain the catheter in the epidural space (Yeager et al. 2016).

There are instances of inadequate analgesia in the cephalad and caudal directions, of unilateral analgesia, and of analgesia completely deviating from the target segments, often experienced in epidurals. An excessively wide analgesic area can result in unnecessary sensory and motor blocks in some patients. Such problems are often difficult to manage (Yokoyama et al. 2004).

The present study used the technique of lumbar epidurography, after epidural catheterization, hoping that quantitative (degree of dye spread and tip location) and qualitative (distribution of dye spread) characteristics of the epidurograms could be used as a potential guide to the management of postoperative epidural analgesia. It is supposed that the characteristics of epidural dye spread would predict the clinical function of epidural catheters after surgery. The results could be used to guide future quality improvement initiatives.

Methods

The study was conducted in EL-Demerdash Hospitals and the National Institute of Urology and Nephrology after approval from the Research Ethics Committee, Faculty of Medicine, Ain Shams University (Code 39/2017, on January 24, 2107). Seventy patients (50 to 75 years old) scheduled for urological surgeries with incisions up to T_8 dermatome (e.g., open prostatectomy, radical cystectomy) were enrolled in this study. Informed consent was obtained from all patients.

Inclusion criteria were ASA I-II patients, of either sex or surgeries with incisions up to T_8 dermatome. Exclusion criteria include patients with any contraindication to neuraxial regional anesthesia (infection at the site of injection, patient refusal, coagulopathy or other bleeding diatheses, severe hypovolemia, increased intracranial pressure, or severe stenotic valvular heart disease), patients with a known history of allergy to radiopaque dye, patients with severe abnormalities of the spine limiting the spread of contrast medium, patients with metastases affecting the spine, e.g., metastatic cancer prostate, patients with chronic kidney disease (CKD), and history of sensitivity or adverse reaction to opioids or local anesthetics.

All patients were premedicated with 1–2 mg intravenous midazolam. All patients were preloaded with 7–8 ml/kg crystalloid solution. Baseline heart rate, blood pressure, and oxygen saturation were recorded. Using a full-aseptic technique, the epidural space was localized at the L_2-L_3 level with an 18-tuohy needle, with the bevel of the needle facing the cephalad and using the loss of resistance to air in the sitting position. An assistant helped in obtaining maximal spinal flexion. A median approach was used in all patients. A multi-orifice epidural catheter then was inserted, leaving 4–6 cm of the catheter in the epidural space. Any epidural catheter found on the test dose to be intrathecal or intravascular was removed before induction of general anesthesia and the case was excluded.

To make epidurography, 2–3 ml non-ionic, iso-osmolar contrast media, Omnipaque 240 were injected via the epidural catheter. The contrast medium was injected with the patient in the supine position and the epidural filter removed, as this presents a considerable resistance to flow. If the patient complained of any pain or discomfort, the injection would be halted, at least temporarily. Epidurograms (anterior-posterior and lateral projections) will be obtained using a C-arm image intensifier (Figs. 1 and 2).

The epidurograms were examined for the following:

1. Location of the catheter tip in relation to the vertebral body.
2. Extent of dye spread (number of vertebral bodies above and below catheter tip location)
3. Laterality of dye spread (midline, right, or left)
4. Presence or absence of dye spread anterior to the spinal cord on a lateral image.

After epidurogarphy, the epidural block was established with a total of 12–15 ml bupivacaine 0.25% with 50 μg fentanyl over a period of 10 min, to achieve a block to T_8-T_{10}. Two additional 5-ml boluses of 0.25% bupivacaine were given if the block level was not achieved in 15–20 min. The epidural was considered failed if the sensory level was not achieved in 30 min, and the case was excluded.

After the establishment of epidural analgesia, general anesthesia was induced with propofol 1.5–2 mg/kg, fentanyl 1μg/kg, and atracurium 0.5–0.6 mg/kg to facilitate tracheal intubation. Isoflurane was used for the maintenance of anesthesia. Intraoperative analgesia was maintained by a 5-ml epidural bolus of 0.25% bupivacaine every hour.

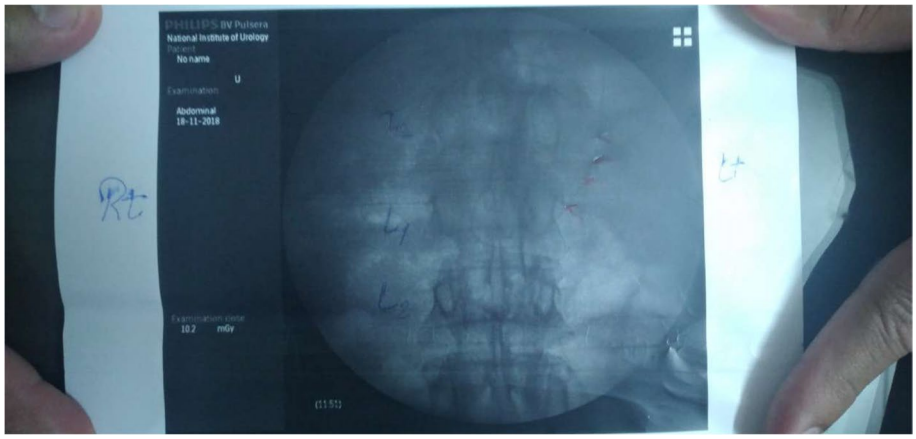


Fig. 1 Antero-posterior image, showing the catheter on the left side with the tip coiled at the level of L1. The dye is noticed to be left-sided, i.e., on the left side of vertebral spines

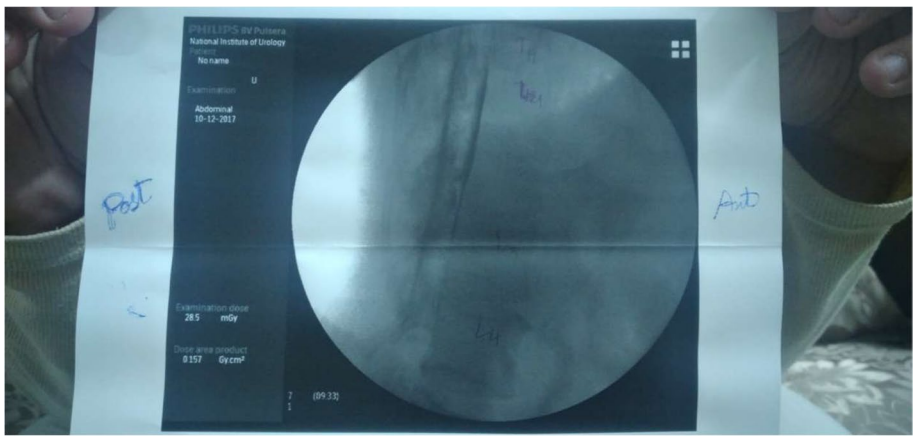


Fig. 2 A lateral image showing anterior and posterior columns of contrast, the dye spread to the anterior epidural space

At the end of surgery and transfer to PACU, we started the infusion rate at 4 ml/h. Pain management was achieved exclusively by this continuous epidural infusion of bupivacaine 0.125% (1.25mg.ml^{-1}) with fentanyl (2μg.ml^{-1}). The patients were followed postoperatively every 4 h for 24 h. This then was modified according to the patient's VAS, and his or her demand in every postoperative visit. In general, a VAS score of 30 mm or less is considered appropriate, and then, there was no need to adjust the infusion rate. Data that were recorded include the following:

1. Rate of analgesic infusion in the postoperative day 1.
2. Visual analog scale (VAS) on postoperative day 1. VAS is a 10-cm line with 0 at one end representing "no pain," whereas 10 cm at the other end representing "the worst imaginable pain."
3. Dermatomal level of sensory deficit to cold (ice).

Data were assessed every 4 h for 24 h.

Statistical analysis

The calculation of sample size was mainly based on the difference in the mean value of epidural infusion rate of local anesthetics according to catheter tip location in epidurograms. Based on a previous study (Yeager et al. 2016) and the assumption that data are normally distributed, an estimation of the sample size was performed using the program GPower3.1. For an effect size of 0.5, assuming a two-sided type I error of 0.05 and a power of 0.80, a sample size of 70 patients was required.

The quantitative data were presented as mean, standard deviations, and ranges when parametric and median, and inter-quartile range (IQR) when data were found

non-parametric. Also, qualitative variables were presented as numbers and percentages. Qualitative data was compared by using *chi-square test* and/or *Fisher's exact test* when the expected count in any cell was found less than 5. Quantitative data and non-parametric distribution were compared by using *Mann-Whitney test.* The comparison between quantitative data and non-parametric distribution was done by using *Kruskall-Wallis test.*

Spearman correlation coefficients were used to assess the correlation between two quantitative parameters in the same group. The confidence interval was set to 95%, and the margin of error accepted was set to 5%. So, the *p* value was considered significant as the following: *p* value > 0.05: non-significant (NS); *p* value < 0.05: significant (S); and *p* value < 0.01: highly significant (HS).

Results

Table 1 shows the demographic data and technical fluoroscopic characteristics of epidural catheters, in this study.

Epidural catheters were inserted at the L_2-L_3 level, on the basis of anatomical surface landmarks, especially Tuffier's line. The catheters were threaded upwards for 4–6 cm. This resulted in catheter tips located at either L_1 or L_2 (50% each).

The median was used to describe the vertical spread of dye above or below the catheter tip, with a range of 5–9 vertebrae. Most of the catheters (70%) showed mid-line aggregation of the contrast medium. A unilateral dye spread pattern (30%) tended to favor right-sided spread over left-sided spread by a ratio of 2:1.

Fifty percent of catheters were associated with the anterior spread of the dye study on the lateral fluoroscopic images.

When we statistically correlated the postoperative infusion epidural rate and VAS scores with the two catheter tip locations (L_1 or L_2 vertebrae), L_1-ended catheters showed a lower rate of epidural analgesic infusion and lower VAS scores (Fig. 3).

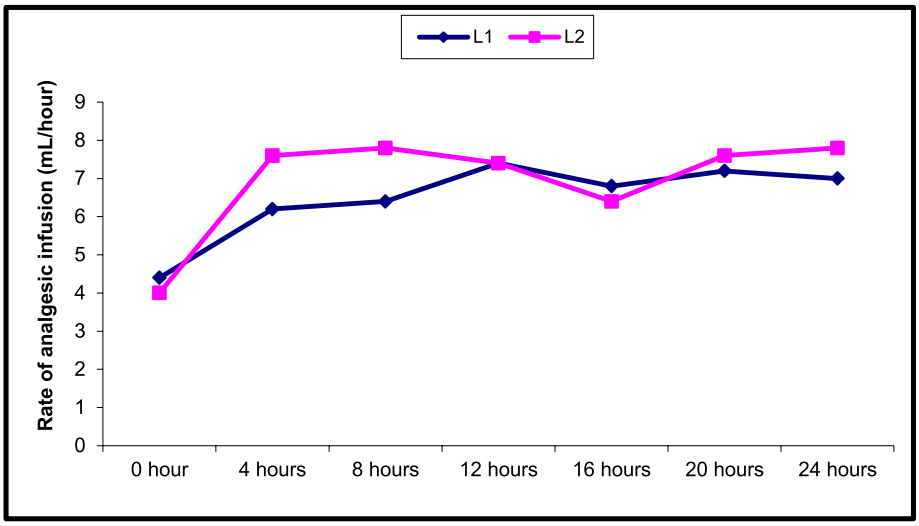
As the vertical spread of the dye increases in preoperative epidurograms (represented by the number of vertebral bodies above and below the catheter tip), both the analgesic infusion rate and VAS scores decrease, and the number of dermatomes showing anesthesia to cold increases. The findings, however, were not consistent throughout the first postoperative day at all times. Of note, the radiographic spread areas always were larger than the number of dermatomes developing anesthesia to ice cold postoperatively.

Asymmetry of contrast distribution was studied with asymmetry in sensory testing on the first postoperative day. The study revealed more dermatomes deficient to cold sensations on the right side postoperatively with epidurographically right-sided catheters, compared with mid-line and left-sided catheters. Nevertheless, this correlation was not found in epidurographically left-sided catheters. The left-sided catheters represented only 10% of the 70 catheters in the study.

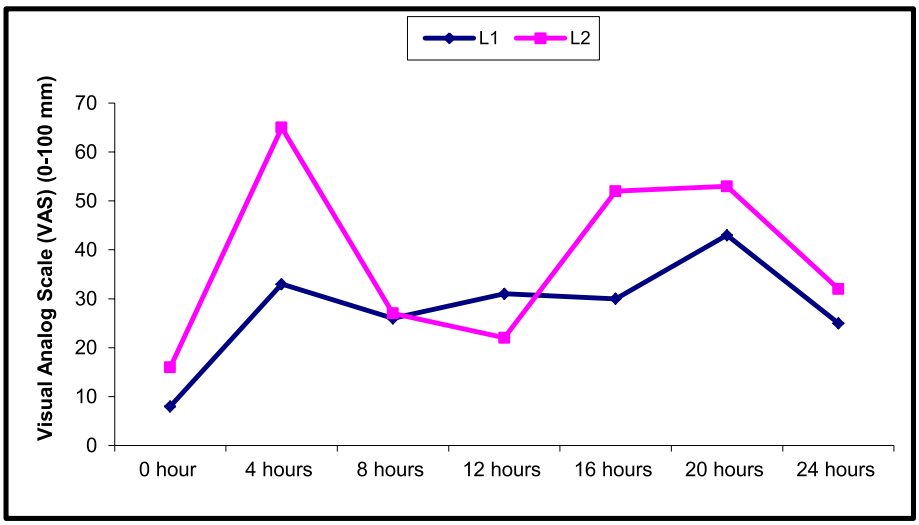
Statistical analysis was used to study the relationship between the significance of the spill of contrast anterior to the spinal cord in lateral images, and postoperative

Table 1 Demographic and fluoroscopic characteristics of epidurals in the studied patients

		Total no. = 70
Age	Mean ± SD	65.1 ± 7.56
	Range	50–75
ASA	II	70 (100.0%)
Type of surgery	Open prostatectomy	21 (30.0%)
	Open cystolithotomy	7 (10.0%)
	Radical prostatectomy	14 (20.0%)
	Radical cystectomy	28 (40.0%)
Duration of surgery (hours)	Mean ± SD	5.1 ± 2.13
	Range	2–8
Location of the epidural catheter tip in relation to vertebral bodies	L_1	35 (50.0%)
	L_2	35 (50.0%)
Number of vertebral bodies above and below catheter tip location	Median (IQR)	6.5 (6–8)
	Range	5–9
Laterality of dye spread in antero-posterior images	Right	14 (20.0%)
	Mid-line (central)	49 (70.0%)
	Left	7 (10.0%)
Dye spread anterior to the spinal cord in lateral images	No	35 (50.0%)
	Yes	35 (50.0%)



(a)



(b)

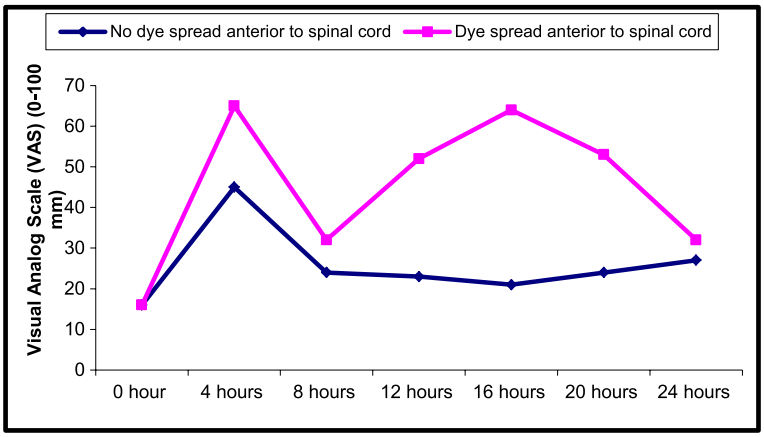
Fig. 3 **a** The rate of infusion was higher for L_2 catheters, at 4 and 8 h postoperatively. **b** VAS scores are lower with L_1 catheters

analgesia and sensory data. It seemed that restriction of contrast to the posterior epidural space was associated with lower VAS scores and wider anesthetic blockade to cold (Fig. 4). Again, these results are not consistent.

Discussion

Over the last decade, few researchers performed epidurography perioperatively to study various aspects associated with epidural anesthesia and analgesia. It was used to study either failed or complicated epidural blocks (Collier 2012) and to determine the appropriate length of catheters in the epidural space (Afshan et al. 2011). Others used epidurography in selected cases to determine whether to depend on epidural catheters or not in postoperative pain management (Boshier et al. 2019)

Epidurography was used in this single-arm clinical trial to correlate certain fluoroscopic characteristics of epidural catheters (like vertical dye spread, location of the catheter tip, or anterior spread of the dye) and clinical function on postoperative day 1 (VAS scores, sensory deficit to ice, and epidural infusion rate). The present study is similar to an exploratory analysis investigating both thoracic and lumbar epidural catheters epidurographically and clinically (Yeager et al. 2016). We only studied lumbar epidural catheters in urological patients.



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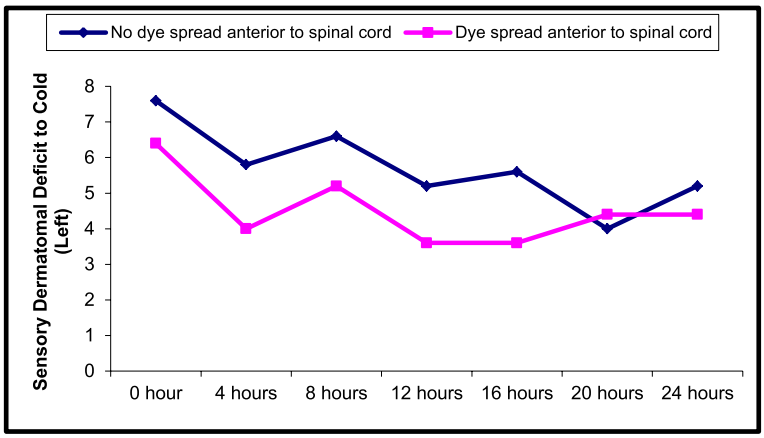

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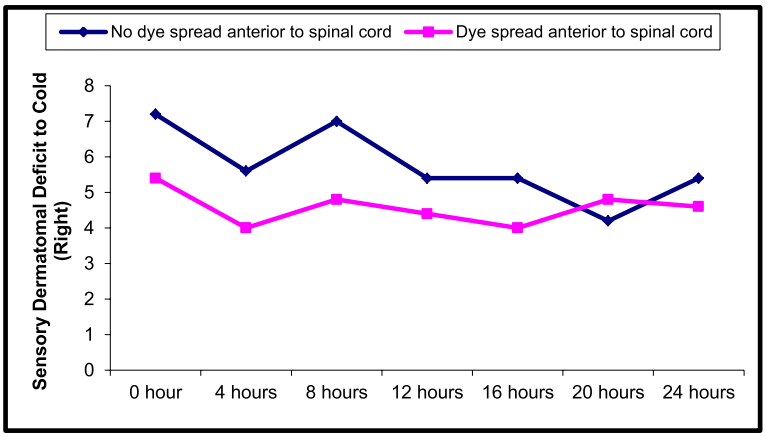

(c)

Fig. 4 **a** Lower VAS scores with NO anterior dye spill. **b** Wider deficit on the left side with NO anterior dye spread. **c** Wider dermatomal block on the right side with NO anterior dye spill

The lowest rate of epidural infusion was 4.2 ml/h, corresponding to 5.25 mg/h of bupivacaine, and 8.4 μg/h of fentanyl. The highest rate of infusion was 7.4 ml/h, corresponding to 9.25 mg/h of bupivacaine, and 14.8μg/h of fentanyl. These infusion rates are comparatively low, possibly owing to the old mean age (65.1 ± 7.56), and the decreasing analgesic requirements with age.

The epidural catheter tips were found by fluoroscopy to be located at either L_1 or L_2 (50% each) while the catheter insertion site was at the L_2-L_3 level, as indicated by Tuffier's line. By comparing the rates of epidural infusion and VAS scores in L_1-ended catheters and L_2-ended catheters, L_1-ended catheters showed lower infusion rates and much lower VAS scores. Yeager et al. (2016) displayed a positive correlation between epidural catheter tip locations at thoracic vertebrae and VAS scores in thoracotomy patients.

In this study, the median value of total vertical radiographic spread was 6.5 segments, with a range of 5–9, when a 3-ml contrast medium was injected. We found that the number of vertebral segments, to which the dye spread vertically in preoperative epidurograms, correlated well with the number of skin dermatomes that developed anesthesia to cold with a postoperative anesthetic infusion. The correlation was stronger on the right side than on the left side and was not readily manifest at all times of assessment postoperatively. The number representing vertical dye spread was always greater than the number of dermatomes blocked. There is much controversy about whether the vertical distribution of contrast would exactly mimic the vertical distribution of clinical local anesthetic. Some failed to elicit such correlation (Slappendel et al. 1988). Others concluded that epidurography could provide an estimate of the extension of an epidural block, but cannot predict the exact segmental distribution of the block (Yokoyama et al. 2004; Sjøgren et al. 1989). Because of variable extrinsic and intrinsic factors affecting the distribution of injected solution into the epidural space, epidurography still cannot predict the exact dermatomes blocked by the epidural technique. The radiographic area often overestimates the analgesic area to variable degrees, but they are more or less correlated positively.

Seventy percent of epidural catheters (49 from 70) have displayed a bilateral spread of contrast, whereas 30% have displayed unilateral spread; 20% (14 from 70) were right, and 10% (7 from 70) were left. We tried to elicit a relationship between catheters showing asymmetry of contrast spread in preoperative epidurograms and the degree of asymmetry of a sensory block on the right and left sides. We failed to show that tendency of contrast to go to the left side resulted in a larger sensory deficit on this side when tested on patients, but epidurographically right-sided catheters did show more dermatomes deficient to cold sensations on the right side postoperatively. Yeager et al. (2016), however, stated that laterality or asymmetry of dye spread (right- or left-sided) on an epidurogram was associated with asymmetry of sensory testing on the first postoperative day. The number of epidural catheters showing a left-sided spread of contrast in our study was only 7 from 70 catheters (only 10%); most probably, the relationship was not manifested on the left side because of this small number.

This study displayed that patients with vertical dye spread greater than 6.5 vertebral segments had significantly lower infusion rates compared to patients with more limited dye spread. These patients also manifested lower VAS scores postoperatively. These findings were not achieved consistently at all times of assessment on the first postoperative day. Yeager et al. (2016), on the other hand, have reached the same result but with less vertical dye spread (2.5 segments). The large discrepancy in vertical contrast spread between this study and Yeager's study (6.5 vs. 2.5) may be caused by the different sites of epidural catheterization; we studied lumbar epidural catheters but Yeager et al. studied thoracic ones. In addition, the mean age group in this study was relatively high (65.1 ± 7.56). Yeager et al. (2016) observed that advanced age was associated with greater dye distribution on an epidurogram.

The localized aggregation of contrast to the posterior epidural space, without spill anterior to the spinal cord, was associated with lower VAS scores, and wider dermatomal anesthetic blockade to cold. Fifty percent of our lumbar epidural catheters displayed anterior spill of contrast in the lateral fluoroscopic images. On the contrary, Yeager et al. (2016) found that anterior spread of dye was noticed only in 8.9% of their thoracic epidural catheters. Patients with anterior dye spread had significantly lower infusion rates compared to patients with no anterior visualization of dye. There is controversy about the real existence of the anterior epidural space. Collier (2012) clearly stated that contrast filling of the anterior space in the upper thoracic spine was seen, but only rarely. Others said that the dura and the posterior longitudinal ligament are fused in this mid-thoracic area, and thus, the space there is obliterated (Seeling et al. 1995). Hogan (2009) has claimed that the fusion between the dura and the posterior longitudinal ligament is only intermittent. He described however a fine membrane, which he called the fascia of the posterior longitudinal ligament. This membrane stretches laterally from the posterior longitudinal ligament and completely separates the anterior epidural compartment from the rest of the vertebral canal. Hogan (2009) stated that this membrane effectively blocks the spread of injected solution from passing anterior to the

plane of the posterior longitudinal ligament and funnels the solution toward the spinal nerves.

Conclusions

Epidurography can be used to determine certain features of epidural catheters, which may guide physicians to optimum postoperative pain management.

Abbreviations

T_8: Eighth thoracic dermatome; L_2: Second lumbar vertebra; L_3: Third lumbar vertebra; VAS: Visual analog scale; L_1: First lumbar vertebra; ™: Trademark; ASA: American Society of Anesthesiologists; CKD: Chronic kidney disease; T_{10}: Tenth thoracic vertebra; IQR: Inter-quartile range; NS: Non-significant; S: Significant; HS: Highly significant; SD: Standard deviation.

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Authors' contributions

MS: follow-up of the patients, collection, analysis of the data, and paper submission. EA: design of the work. FS: design of the work, revision of literature, and critical revision of the manuscript. AH: analysis, interpretation of the data, and contribution to the paper writing. SM: design of the work, work revision, contribution to the paper writing, and critical revision of the manuscript. The authors have read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This single-arm clinical trial was conducted after approval of the Research Ethics Committee of the Faculty of Medicine, Ain Shams University, and after obtaining informed consent from all patients.
Approval number: FMASU MS Code 39/2017, on date 24/1/2107.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have competing interests.

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