Impact of Epidural Catheter-Incision Congruency on Postoperative Analgesia after Major Abdominal Surgery: An Observational Study in a Teaching Hospital

Ali Sarfraz Siddiqui[1], Usama Ahmed[2] and Gauhar Afshan[1]

[1]*Department of Anaesthesiology, The Aga Khan University Hospital, Karachi, Pakistan*
[2]*Pain Medicine and Anaesthetics, Frimley Health NHS Foundation Trust, Frimley, United Kingdom*

ABSTRACT

Objective: To determine the frequency of appropriate epidural catheter-incision congruency in adult patients undergoing major abdominal surgeries, as well as the frequency of ineffective postoperative analgesia with continuous epidural infusion, side effects, and complications of epidural insertion and epidural catheter infusion.

Study Design: Observational study.

Place and Duration of the Study: Department of Anaesthesiology, The Aga Khan University Hospital, Karachi, Pakistan, from September to November 2022.

Methodology: All adult patients who underwent elective major abdominal surgery under general anaesthesia with epidural analgesia were included in this study. Data were collected by chart review of the patients enrolled in Acute Pain Service for the study period. Intraoperative anaesthesia form, epidural infusion form and all records of acute pain service for the postoperative period were reviewed and recorded.

Results: One hundred and eighty-two patients were included in this study. The epidural catheter was inserted congruent to the surgical incision i.e. T10-T11 level or above in 43 (23.6%) patients only. In the postoperative period, overall effective epidural analgesia was observed in 79 (43.4%) of the patients. Motor block in lower limbs was observed in 66 (36.26%) of patients in the immediate postoperative period.

Conclusion: The present study shows appropriate epidural catheter-incision congruency in only 23.6% of the patients. This could be one of the common reasons for ineffective postoperative pain relief *via* epidural analgesia in 56.6% of patients.

Key Words: *Epidural catheter insertion site, Major abdominal surgeries, Postoperative analgesia.*

How to cite this article: Siddiqui AS, Ahmed U, Afshan G. Impact of Epidural Catheter-Incision Congruency on Postoperative Analgesia after Major Abdominal Surgery: An Observational Study in a Teaching Hospital. *J Coll Physicians Surg Pak* 2024; **34(07)**:751-756.

INTRODUCTION

Moderate to severe postoperative pain and the stress response to major abdominal surgery may cause significant morbidities in multiple human organ systems. Several studies demonstrated the use of epidural analgesia (EA) for postoperative pain control and better patient outcomes. EA with local anaesthetic is better as compared to patient-controlled intravenous analgesia using morphine in the early postoperative period.[1] EA, an important component of multimodal analgesia, has been considered a technique of the choice for the open abdominal surgeries. It has been shown that EA at the thoracic level reduces pain, improves bowel function, fastens the recovery, and improves patient satisfaction after abdominal surgeries when compared with the intravenous opioids.[2]

Correspondence to: Dr. Ali Sarfraz Siddiqui, Department of Anaesthesiology, The Aga Khan University Hospital, Karachi, Pakistan
E-mail: sarfraz.siddiqui@aku.edu
Received: March 14, 2024; Revised: June 04, 2024; Accepted: June 11, 2024
DOI: https://doi.org/10.29271/jcpsp.2024.07.751

Continuous EA is commonly used for postoperative pain control after thoracic, abdominal, and lower extremity surgeries. For effective EA, epidural catheter placement is crucial and must be placed at a level determined by the dermatomal level of the planned surgery. This is called an epidural catheter-incision congruency and is achieved when the epidural catheter corresponds to the dermatomes of the surgical incision i.e. thoracic epidural catheters for thoracic or abdominal surgery and lumbar epidural catheters for lower extremity surgery.[3]

Incorrect placement of the epidural catheter is not uncommon and is one of the leading causes of inadequate analgesia, especially when the catheter is placed preoperatively before general anaesthesia. The reported incidence of failure of postoperative EA is between 13% and 41%, depending on the definition of failure.[4] Inadequate EA may result from several causes related to the patient or surgical factors and epidural catheter including catheter-incision incongruency. Current literature supports the epidural catheter placement to thoracic level T8-11 for all the major abdominal surgeries with a catheter length of 5 to 6 cm into the epidural space.[5,6]

In this institution, many patients undergo major abdominal surgeries and need effective EA for better outcomes. A dedi-

cated acute pain service (APS) consisting of anaesthesia consultants, residents, pain medicine fellows, and nurses manages the patients after major surgery by using a multi-modal analgesia regimen. The impact of epidural catheter-incision congruency in the patient population has never been investigated. The rationale of the present study was to evaluate the current practice of EA considering catheter-incision congruency. The primary objective was to calculate the frequency of appropriate epidural catheter-incision congruency in adult patients undergoing major abdominal surgeries. The secondary objectives were to determine the frequency of ineffective postoperative analgesia with continuous epidural infusion, side effects, and complications of epidural insertion and epidural catheter infusion (like motor block, hypotension, dural tap, and post-dural puncture headache).

METHODOLOGY

This observational study was retrospectively conducted at the Department of Anaesthesiology, The Aga Khan University Hospital, Karachi, Pakistan, after obtaining approval from the Institutional Ethical Review Committee. All adult patients, who underwent elective major abdominal surgery under general anaesthesia with EA and managed by acute pain service (APS) were included. Those adult patients who underwent emergency surgery and in whom epidural catheter was removed in the immediate postoperative period because it was ineffective were excluded from this study.

Data were collected retrospectively from September to November 2022 by the chart review of patients enrolled in APS from 1st July 2021 to 30th June 2022. Variables have been defined for the review and a form has been designed for the data collection. Intraoperative anaesthesia form and epidural infusion form were reviewed for records of epidural insertion (site of insertion, length of the catheter in epidural space, side effects, and complications). Patients' medical records were reviewed for surgical incision, epidural infusion form (drug, dose, and rate), postoperative patient assessment (static and dynamic pain score, any additional analgesia provided, rescue analgesia needed, motor block, nausea, or vomiting), and reason for epidural discontinuation. In this study, an epidural catheter inserted at thoracic level T10-T11 or above was considered appropriate.[5] Postoperative analgesia was considered ineffective when the pain score was 4/10 or more on the numeric rating scale (NRS) scale with continuous infusion of local anaesthetic epidurally and opioid bolus or infusion was needed to treat pain.

Data were entered and analysed using Statistical Package for Social Science (SPSS) version 19 (Chicago, Illinois). To assess the normality assumption of numerical variables, the Shapiro-Wilk or Kolmogorov-Smirnov test were conducted. Mean ± SD or median ± IQR were calculated for normal and non-normal data, respectively. Categorical variables such as primary surgical speciality, ASA physical status, surgical procedure, and other variables were presented in terms of frequency and proportion.

RESULTS

One hundred and eighty-two patients were included in this study. Ninety-six (52.75%) of patients were males and 86 (47.25%) were females. Demographical variables, ASA statuses, and comorbid conditions are presented in Table I. One hundred and sixty-one (88.5%) patients underwent surgeries due to cancer. These included major general surgeries in 104 (57.1%), gynaecological surgeries in 46 (25.2%), urological procedures in 19 (10.4%), and esophagectomy in 13 (7.14%).

All patients received general anaesthesia (GA) with EA. The epidural catheter was inserted in the sitting position before GA in 167 patients (91.8%), and 15 patients (8.24%) had an epidural catheter placed in the lateral position after GA. The epidural catheter was placed by an anaesthesia consultant in one hundred and 23 (67.6%) patients and by a senior resident in 59 (32.4%) patients. Intraoperatively, epidural infusion of bupivacaine was continued for analgesia in 30 patients (16.5%). One hundred and fifty-two patients also received intraoperative co-analgesia (like morphine, nalbuphine, tramadol, paracetamol, ketorolac, or dexmedetomidine).

The epidural catheter was inserted at T10-T11 level or above in 43 (23.6%) patients, below T11 but till L1 in 73 patients (40.15%) and below L1 in 66 (36.3%) patients. Considering the recommendation of epidural insertion for major abdominal surgeries at T10-T11 or above, only 43 (23.6%) of patients had appropriate placement of epidural catheter as congruent to surgical incision, and 139 (76.4%) patients had epidural catheter incongruent to surgical incision presented in Table II.

Epidural space was found between 3 to 5 cm from the skin in 133 patients (73.03%) and catheter length in the epidural space was between 4 to 6 cm in 161 (88.46%) of the patients. In 112 (61.5%) patients, epidural infusion was discontinued and the catheter was removed on the third postoperative day, in 64 (35.2%) patients, it was removed on the second, and in only two patients it was removed on the fourth day. In four patients, the epidural infusion was discontinued, and the catheter was removed on the first postoperative day because it was ineffective for analgesia and caused motor block.

In the postoperative period, overall effective EA was observed in 79 (43.4%) patients while EA was ineffective in one hundred three (56.6%) of the patients. The analgesic regimen was considered ineffective when the pain score was 4/10 or more with continuous infusion of local anaesthetic epidurally and intravenous opioid bolus or infusion was needed to treat pain (Table II). In the recovery room, the median static pain score was 3.0 and the median dynamic pain score was 4.0. On the first postoperative day, the median static pain score was 1.0 and the median dynamic pain score was 3.0. On the second postoperative day, the median static pain score was 1.0 and the median dynamic pain score was 2.0 as presented in Figure 1.

Table I: Demographical variables, ASA status, and comorbid conditions.

Variable	Total (n = 182)
Age (years)	
Mean (SD)	53.5 (14.2)
Gender	
Male	96 (52.75%)
Female	86 (47.25%)
Weight (kg)	
Mean (SD)	69.4 (16.0)
Height (cm)	
Mean (SD)	161 (9.50)
BMI (kg/m^2)	
Mean (SD)	26.7 (6.23)
ASA Physical Status	
I	7 (3.85%)
II	122 (67.0%)
III	53 (29.1%)
Comorbid conditions	
DM, HTN	36 (36.7%)
HTN, IHD	42 (42.9%)
Asthma, COPD	3 (3.06%)
Others	17 (17.3%)

Table II: Epidural catheter-insertion site and overall effectiveness.

Epidural catheter-insertion site	Total (n = 182)
Appropriate	43 (23.6%)
Inappropriate	139 (76.4%)
The overall effectiveness of postoperative analgesia	
Yes	79 (43.4%)
No	103 (56.6%)

Table III: Recovery room variables (n = 182).

NRS pain score (static)	
Median (IQR)	3.00 (1.0)
NRS pain score (dynamic)	
Median (IQR)	4.00 (2.0)
Motor-block	**66 (36.26%)**
Right lower limb	13
Left lower limb	10
Both lower limbs	43
Rescue analgesia given	92 (50.54%)
Epidural bolus	39
Intravenous analgesics	88
Complications	
Hypotension	3

The motor block was observed in 66 (36.26%) patients in the recovery room. Forty-three patients had a motor block in both lower limbs. On the first postoperative day, the motor block was present in 66 (36.26%) of the patients. Nine patients had a motor block in both lower limbs while 57 patients had a motor block in one limb. On the second postoperative day, motor block was observed in 21 patients in which three patients had a motor block in both lower limbs while 18 patients had a motor block in one limb. On the third postoperative day, the motor block was present in one limb in six patients.

In the recovery room, 92 (50.54%) of patients received rescue analgesia. Thirty-nine patients received an epidural bolus dose of bupivacaine and 88 patients received intravenous analgesics (opioids and non-opioids drugs) to manage pain (Table III). Regarding complications related to epidural catheter insertion, four patients had a dural tap during epidural insertion (three with the epidural needle and one with the catheter). No patient developed post-dural puncture headache, and all were managed routinely. Regarding complications related to epidural infusion, hypotension was observed in three patients in the recovery room and three patients in the ward. All patients were managed by intravenous fluids and by titrating the infusion rate of epidural bupivacaine.

In the subgroup analysis, approximately 80% of the patients showed overall effective analgesia in those patients in whom an epidural catheter was placed at the appropriate site (T10 / T11 or above, congruent to the surgical incision). Approximately 70% of the patients showed overall ineffective analgesia in those patients in whom an epidural catheter was not placed at the appropriate site (incongruent with the surgical incision). In 66 patients, the epidural catheter was inserted below the L1 level (L1/L2 = 26, L2/L3 = 17, L3/L4 = 17, and L4/L5 = 6). In 161 patients, epidural catheter length in the epidural space was between 4 to 6 cm while in 19 patients, epidural catheter length in the epidural space was more than 6 cm.

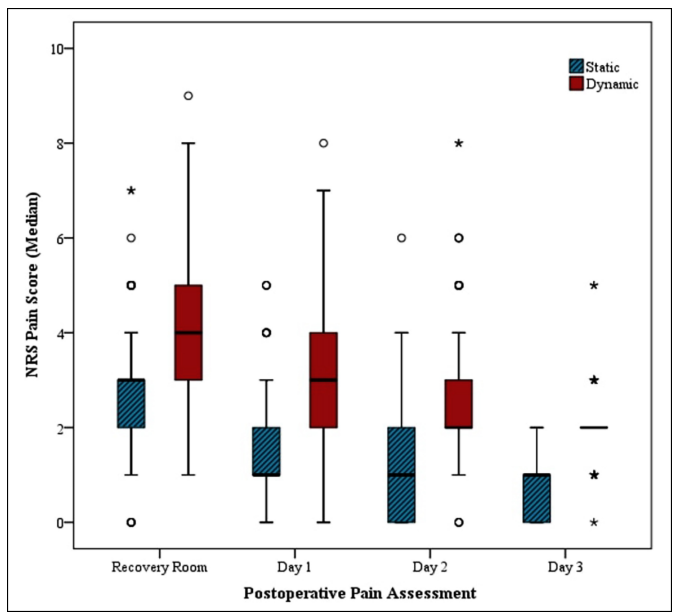

Figure 1: Postoperative pain assessment (static and dynamic).

DISCUSSION

The study showed effective epidural analgesia in 43.4% of the patients *via* physician-controlled epidural catheter-infusion. This is quite low in comparison to 68-70% of effective analgesia by thoracic epidural mentioned in the literature.[7] The primary epidural failure usually occurs due to an incorrect catheter insertion site, inadvertent dural puncture, and intravascular insertion of the catheter. Secondary failure is the initial functioning and then subsequent failure. In terms of severity, there is a variable criterion between studies, but all studies conclude that the strongest standpoint to declare epidural failure is the need to re-site the catheter.[8] The majority of the available

literature serves to differentiate between the primary and secondary failure only. After a thorough literature search and to the best of the authors' knowledge, epidural catheter and corresponding vertebral congruency have not been investigated earlier in the evaluation of the causes of failed epidural that is presented in this study.

The current recommendation suggests the use of epidural analgesia in open major abdominal cancer and non-cancer operations, gynaecological oncology surgeries, radical cystectomy, and esophagectomy.[9] The prime factor in epidural catheter success is the correct localisation of the space and placement of the epidural catheter congruent to the surgical incision. This is particularly challenging for the thoracic vertebral area because of the relevant anatomy. Many factors have been identified which include but are not limited to operator experience, patient positioning, body habitus, and spine anatomy.[10]

Landmark-mediated vertebral level identification is reported to be accurate in only 30% of the cases.[10] Anatomical landmarks are the primary method of vertebral level identification in this institute which is one of the reasons for the lower level of epidural catheter insertion. The method of palpation is usually considered easier and therefore has wider adoption.[11] The other important reason is the relative ease of insertion and fewer chances of complications at the lumbar vertebral levels compared to thoracic vertebrae due to the acute angulation of spinous processes.[12] This study's results contrast with the usual tendency of anaesthesiologists to site the epidural at a higher than intended vertebral level. In this study, an epidural catheter was inserted at two to three vertebral levels lower.[15] Appropriate epidural insertion was found in patients with a body mass index (BMI) less than 30 kg/m^2. This is consistent with the known risk factor of difficult neuraxial anaesthesia.[13]

The principal site of action of epidurally administered local anaesthetics is the spinal nerve roots as they traverse the epidural space in addition to the spinal cord *via* diffusion through the meninges. Therefore, to numb the target dermatomes, the corresponding nerve roots must be blocked which can be achieved by their contact with the local anaesthetic.[11] To compensate for the higher levels of local anaesthetic spread due to lower levels of epidural catheter placement, more volume and boluses had to be given in this study which resulted in hypotension and motor blockade. Motor block can be attributed to the dosage of local anaesthetic. There is an extended sensory and motor block as well as lower arterial pressure with a higher volume of local anaesthetics. Though hypotension was observed in a few patients, the incidence of lower limb motor blockade was found to be 36.26%, of which the majority was found to be bilateral.

In an observational study for the quest of motor blockade with epidural catheters, 36.5% of patients were found to have a motor blockade of variable degrees. Similarly in this study's patients, motor blockade occurred more commonly with lumbar epidurals. This is the most common complication of epidurals encountered by APS globally. Lower thoracic epidurals are therefore recommended for abdominal surgeries for effective pain control and motor sparing.[14]

Dose control of local anaesthetics at the thoracic vertebral level can lead to a true segmental block affecting only the thoracic area. Lumbar and sacral nerves can be spared, preventing extensive sympathetic block, hypotension, bladder dysfunction, as well as lower limb motor block. This can be achieved with correct vertebral level identification by use of ultrasound which was not employed in any of the cases in this study.[15]

Most of the epidurals (91.8%) were inserted in an awake and sitting position. This position is the least time-consuming with a higher first-attempt success rate. This can be correlated to the 77.9% first-attempt success rates in this study's patients. One of the drawbacks related to this positioning is increased vagal reflexes, none of which were reported in this study's patients. Insertion of an epidural in the awake patient confers two advantages: The quality of pain warns the anaesthetist of any potential neurological damage, and the extent of sensory analgesia can be measured in awake patients before general anaesthesia.[16]

In this study, four cases of dural puncture were noted. Three occurred with the needle and one with the catheter making up the puncture complication of 2.2% which is relatively higher than reported incidences of 0.4 – 1.2%. Dural perforation is found to occur more in the lower thoracic than in middle or upper-thoracic spine placements. Therefore, it demands caution and boluses only after the negative aspiration of cerebrospinal fluid (CSF).[17]

Epidural space has three compartments relative to the spinal cord: Posterior, lateral, and anterior. The posterior epidural space is most relevant for the catheters for post-surgical pain. In this study, the catheter length in the epidural space was observed between 3 to 11 cm. A 5 cm catheter length inside the epidural space was observed in 47.8% of the patients. A longer length of the epidural catheter in the epidural space increases the likelihood of a unilateral block or intravenous cannulation. Less than 3 cm catheter length has the potential for displacement out of the epidural space. Any length beyond 5 cm increases the risk of unilateral dense block and possible transforaminal escape.[18] The recommended length of catheter in the epidural space for effective postoperative analgesia is 5 cm.[19] The effectiveness of epidural analgesia was found independent of the length of the catheter in the epidural space in this study.

For epidural boluses and continuous infusion, bupivacaine was used without adjuncts. A concentration of 0.1% was used in 96% of the cases and 0.0625% in 4% of the cases. Bupivacaine is more potent and cheaper compared to ropivacaine and is used in low- and middle-income countries (LMICs). In terms of analgesic efficacy, it is equal to ropivacaine. Changing the local anaesthetic agent does not improve epidural efficacy. For bolus dosing, reduction of dose increases the probability of differential block. In healthy volunteers, dose-dependency of the differ-

ential block has been demonstrated with bupivacaine 0.075 and 0.125%.[20]

In teaching hospitals, the primary failure of epidural analgesia may be due to many factors. Inadequate training, learning curves are non-existent, pedagogical requirements are often inadequate, lack of experienced supervisors, and exposure during training.[21] This study was done in a university teaching hospital with a structured residency programme. It was found that 32.4% of epidurals were inserted by a senior resident of which only 16% of the catheters were congruent with the surgical incision. Residents need to complete approximately 20-25 procedures to demonstrate improvement in the skills of spinal and epidural anaesthesia. For a 90% success rate, 45 and 60 attempts at spinal and epidural anaesthesia, respectively, may be necessary for a trainee.[22]

The breakthrough pain may be due to inadequate block, patchy block, unilateral block, and back pain. Epidural re-siting was not done in any of the studied cases despite a higher incidence of ineffective epidurals due to poor logistic support available to the APS, fear of infection among the multidisciplinary team members, and an increase in anaesthesia fee charges to be borne by the patient. The incidence of epidural catheter re-siting varies widely in the literature from 1.6 to 15.4%. Forty-six percent of the cases of secondary epidural failure do not require catheter re-siting and can be resolved with active management such as epidural supplementation. Therefore, in the case of an ineffective epidural, reliance should be on a multimodal regime including patient-controlled intravenous analgesia.[23]

This study highlights the importance of epidural catheter-incision congruency and its impact on postoperative analgesia. This observational study shows that catheter-incision incongruency could be one of the leading causes of inadequate pain relief with several side effects and poor patient satisfaction. Such database observational studies can be used to improve APS, thereby increasing patient satisfaction.

A retrospective review of patients' medical records in a single centre was the major limitation of this study. Although all information as per the planned data collection form was found, standard record-keeping cannot be guaranteed. This study also reflects the practice of only one tertiary care centre with relatively a small sample size. The multicentric study with a large sample size would have given a more holistic view of epidural catheter-incision congruency practice in patients with EA undergoing major abdominal surgery.

The primary epidural failure usually occurs due to an incorrect catheter-insertion site as per surgical incision. Epidural catheter-incision congruency is a relatively new terminology based on the old concept. If epidural analgesia is planned, the catheter should be placed congruent to the surgical incision or expected dermatome involved. This practice would provide effective analgesia with fewer side effects and better patient satisfaction after the surgery. Further prospective multicentric studies and quality audits are needed to improve APS.

CONCLUSION

The frequency of appropriate epidural catheter insertion (T10-T11 level or above) was found in 43 (23.6%) patients only, and the majority of them showed effective analgesia in the postoperative period after major abdominal surgery. Epidural analgesia was found ineffective in 103 (56.6%) patients when catheter-incision was not congruent with other technical failures. Motor block in lower limbs was also observed in 66 (36.26%) of the patients in the immediate postoperative period with ineffective analgesia. An epidural catheter should be placed congruent to the surgical incision to provide effective analgesia with fewer side effects and improved patient satisfaction after major operations.

ETHICAL APPROVAL:

This study was conducted, after obtaining the approval from the Institutional Ethical Review Committee of The Aga Khan University Hospital, Karachi, Pakistan (ERC# 2022-7904-22478).

PATIENTS' CONSENT:

Not applicable.

COMPETING INTEREST:

The authors declared no conflict of interest.

AUTHORS' CONTRIBUTION:

ASS, UA: Concept of the study, design, data analysis, and data interpretation.
GA: Revision for intellectual content.
All authors approved the final version of the manuscript to be published.

REFERENCES

1. Melloul E, Lassen K, Roulin D, Grass F, Perinel J, Adham M, *et al*. Guidelines for perioperative care for pancreatoduodenectomy: Enhanced recovery after surgery (ERAS) recommendations 2019. *World J Surg* 2020; **44(7)**:2056-84. doi:10.1007/s00268-020-05462-w.
2. Weiss R, Popping DM. Is epidural analgesia still a viable option for enhanced recovery after abdominal surgery. *Curr Opin Anaesthesiol* 2018; **31(5)**:622-29. doi:10.1097/ACO.0000000000000640.
3. Su PP, Peniche A, Clelland E, Ladd M, Delgado A, Chen LL, *et al*. Comparison of programmed intermittent epidural bolus and continuous epidural infusion for post-operative analgesia after major abdominal surgery: A randomized controlled trial. *J Clin Anesth* 2020; **64**:109850. doi:10.1016/j.jclinane.2020.109850.
4. Groen JV, Khawar AAJ, Bauer PA, Bonsing BA, Martini CH, Mungroop TH, *et al*. Meta-analysis of epidural analgesia in patients undergoing pancreatoduodenectomy. *BJS Open* 2019; **3(5)**:559-71 doi:10.1002/bjs5.50171.
5. Konigsrainer I, Bredanger S, Drewel-Frohnmeyer R, Vonthein R, Krueger WA, Konigsrainer A, *et al*. Audit of motor weakness and premature catheter dislodgement after epidural analgesia in major abdominal surgery. *Anaesthesia* 2009; **64(1)**:27-31. doi:10.1111/j.1365-2044.2008.05655.x.

6. Ahmed A, Baig T. Incidence of lower limb motor weakness in patients receiving postoperative epidural analgesia and factors associated with it: An observational study. *Saudi J Anaesth* 2016; **10(2)**:149-53. doi:10.4103/1658- 354X.168806.
7. Hermanides J, Hollmann MW, Stevens MF, Lirk P. Failed epidural: Causes and management. *Br J Anaesth* 2012; **109(2)**:144-54. doi:10.1093/bja/aes214.
8. Hetherington J, Lessoway V, Gunka V, Abolmaesumi P, Rohling R. SLIDE: Automatic spine level identification system using a deep convolutional neural network. *Int J Comput Assist Radiol Surg* 2017; **12(7)**:1189-98. doi:10.1007/s11548-017-1575-8.
9. Nelson G, Bakkum-Gamez J, Kalogera E, Glaser G, Altman A, Meyer LA, *et al*. Guidelines for perioperative care in gynecologic/oncology: Enhanced recovery after surgery (ERAS) society recommendations-2019 update. *Int J Gynecol Cancer* 2019; **29(4)**:651-68. doi:10.1136/ijgc-2019-000356.
10. Wranicz P, Andersen H, Nordbo A, Kongsgaard UE. Factors influencing the quality of postoperative epidural analgesia: An observational multicenter study. *Local Reg Anesth* 2014; **7**:39-45. doi:10.2147/LRA.S67153.
11. Jagadish A, Swaminathan S, Bidkar PU, Gupta SL, Adinarayanan S. Ease of lumbar epidural catheter insertion with prepuncture ultrasound as guidance compared with conventional palpatory technique when performed by anesthesiology residents: A randomized controlled trial. *J Anaesthesiol Clin Pharmacol* 2021; **37(2)**:216-20. doi:10.4103/joacp.JOACP_394_19.
12. Sudheshna KD, Gopinath R, Ayya SS, Kar P, Kumar RV. High *vs.* mid thoracic epidural analgesia - A comparative study on the ease of insertion and effects on pain, hemodynamics, and oxygenation in patients undergoing thoracotomies. *Ann Card Anaesth* 2019; **22(4)**:383-7. doi: 10.4103/aca.ACA_169_18.
13. Lee JY, Noh KM, Lee SW, Cho EY, Hong JH. Analysis of factors affecting thoracic epidural anesthesia performance time. *Keimyung Med J* 2020; **39**:33-7. doi: 10.46308/kmj.2020.00024.
14. Howle R, Ng SC, Wong HY, Onwochei D, Desai N. Comparison of analgesic modalities for patients undergoing midline laparotomy: A systematic review and network meta-analysis. *Can J Anaesth* 2022; **69(1)**:140-76. doi:10.1007/s12630-021-02128-6.
15. Aijaz T, Candido KD, Anantamongkol U, Gorelick G, Knezevic NN. The impact of fluoroscopic confirmation of thoracic imaging on accuracy of thoracic epidural catheter placement on postoperative pain control. *Local Reg Anesth* 2018; **11**:49-56. doi:10.2147/LRA.S155984.
16. McClymont W, Celnick D. Techniques of epidural block. *Anaesth Intens Care Med* 2018; **19(11)**:600-6. doi:10.1016/j.mpaic.2018.08.022.
17. Imbelloni LE, Gouveia MA. Low Incidence of neurologic complications during thoracic epidurals: Anatomic explanation. *AJNR Am J Neuroradiol* 2010; **31(10)**:E84. doi:10.3174/ajnr.A2227.
18. Robson MI, Fawcett WJ. Identifying a correctly positioned thoracic epidural catheter for major open surgery. *BJA Educ* 2020; **20(10)**:330-1. doi:10.1016/j.bjae.2020.06.002.
19. Afshan G, Chohan U, Khan FA, Chaudhry N, Khan ZE, Khan AA. Appropriate length of epidural catheter in the epidural space for postoperative analgesia: Evaluation by epidurography. *Anaesthesia* 2011; **66(10)**:913-8. doi:10.1111/j.1365-2044.2011.06820.x.
20. Brennum J, Nielsen PT, Horn A, Arendt-Nielsen L, Secher NH. Quantitative sensory examination of epidural anaesthesia and analgesia in man; dose-response effect of bupivacaine. *Pain* 1994; **56(3)**:315-26. doi:10.1016/0304-3959(94)90170-8.
21. Tran DQ, Van Zundert TC, Aliste J, Engsusophon P, Finlayson RJ. Primary failure of thoracic epidural analgesia in training centers: The invisible elephant? *Reg Anesth Pain Med* 2016; **41(3)**:309-13. doi:10.1097/AAP.0000000000000394.
22. Drake EJ, Coghill J, Sneyd JR. Defining competence in obstetric epidural anaesthesia for inexperienced trainees. *Br J Anaesth* 2015; **114(6)**:951-7. doi:10.1093/bja/aev064.
23. Sng BL, Tan M, Yeoh CJ, Han NR, Sultana R, Assam PN, *et al*. Incidence and risk factors for epidural re-siting in parturients with breakthrough pain during labour epidural analgesia: A cohort study. *Int J Obstet Anesth* 2018; **34**:28-36. doi:10.1016/j.ijoa.2017.12.002.