ISSN: 2717-8161 RESEARCH ARTICLE

New Trend Med Sci 2024; 5(2): 45-52. https://dergipark.org.tr/tr/pub/ntms

Comparison of the Effects of Thoracic Epidural Analgesia in Different Levels on Intraoperative Hemodynamics in Abdominal Surgery: A Prospective Randomized Trial

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Article History
Received 28 July 2023
Accepted 21 May 2024
Published Online 30 May 2024

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Doi:10.56766/ntms.1333910

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Abstract: Our aim was to investigate the effect of thoracic epidural anesthesia (TEA) at different levels on hemodynamic parameters in elderly patients undergoing upper abdominal surgery. This randomized study was conducted on 60 patients aged 65 or above undergoing upper abdominal surgery. The patients were randomized into T6-7 and T9-10 groups, with epidural catheters placed at respective intervertebral spaces. Heart rate, systolic and diastolic blood pressure, mean arterial pressure, were recorded every 5 minutes for 30 minutes after TEA and every 10 minutes intraoperatively. Confirming adequate analgesia and 30 minutes after placement of a thoracic epidural catheter, general anesthesia was induced. Postoperative respiratory function tests, time to ambulation, gastrointestinal motility and length of stay were assessed. Systolic blood pressure (SBP) was statistically lower at minutes 5,80, and 90 in group T9-10 ($p=0.003$, $p=0.007$, $p=0.013$ respectively). At the same minutes, diastolic blood pressure (DBP) ($p<0.001$) and mean arterial pressure (MAP) ($p=0.009$, $p<0.001$ and $p<0.001$, respectively) significantly lower in group T9-10. A difference was observed for heart rate at minutes 10, 60, 80, and 90 ($p<0.001$, $p=0.005$, $p=0.003$ and $p<0.001$, respectively). Groups were different for highest and lowest dermatome with block, return of gastrointestinal motility, and length of stay. ($p=0.003$, $p=0.023$, $p=0.003$, $p=0.009$, respectively). Higher TEA provides more stable hemodynamics, respiratory functions, gastrointestinal motility and shorter length of stay compared to lower TEA. Therefore, we recommend high TEA in upper abdominal surgery. ©2024 NTMS.
Keywords: Upper abdominal surgery; thoracic epidural anesthesia; hemodynamics.

1. Introduction

General anesthesia (GA) and thoracic epidural analgesia (TEA) combination is one of the commonly used anesthesia methods in upper abdominal surgeries [1]. In these patients is provided by thoracic epidural analgesia gold standard for pain relief [2].
Elderly patients should use less drug dosage for

Cite this article as: Kaciroglu A, Dostbil A, Ince I, Aksoy M and Celik SM. Comparison of the Effects of Thoracic Epidural Analgesia in Different Levels on Intraoperative Hemodynamics in Abdomınal Surgery: A Prospective Randomized Trıal. *New Trend Med Sci.* 2024; 5(2):45-52.Doi:10.56766/ntms.1333910.

thoracic epidural analgesia because more segments are blocked in the elderly compared to younger patients with the same drug dose. This is one of the reasons for increased hemodynamic instability in elderly patients [3]. Epidural local anesthetic administration creates autonomic denervation and thus causes vasodilation in the vessels [4]. The reduced cardiac reserve in the elderly, as well as structural alteration in the autonomic nervous system and the arterioles, may contribute to the impaired cardiovascular response to TEA [5].

There are studies evaluating various parameters such as cardiac index, stroke volume index, central venous pressure, and central venous oxygen saturation in high TEA [6]. There are studies in the literature of different levels of epidural analgesia in pigs. However, this study compared lumbar and thoracic epidural analgesia [7]. Different levels of thoracic epidural analgesia are performed in upper abdominal surgery. We noticed that there are not enough studies in the literature on thoracic epidural level selection. For this reason, we wanted to investigate the various effects of different levels of thoracic epidural analgesia.

The aim of this study was to investigate the effect of epidural analgesia at different levels on hemodynamic parameters in elderly patients undergoing upper abdominal surgery. The change in systolic blood pressure between the two groups in the intraoperative period was the primary outcome in this study. Secondary aim was to evaluate the extent of spinal segments blocked, respiratory parameters, time to discharge, and gastrointestinal motility with respect to the level of TEA.

2. Material and Methods

This randomized prospective study was performed on 60 patients aged 65 and above, with American Society of Anaesthesiologists (ASA) scores of I, II, and III, undergoing upper abdominal surgery. Approval of in this study was from the local ethics committe. All participants provided written informed consent.

2.1. Patients

Patients with a history of hypersensitivity or allergy to amide-type local anesthetics, vertebral surgery, cervical or thoracic vertebra arthritis, contraindication of epidural anesthesia (local infection at the site of epidural puncture, nervous system diseases, bleeding diathesis, use of an antiplatelet or anticoagulant agent etc.), uncontrolled hypertension. severe cardiac, respiratory, hepatic, or renal disease, diabetes mellitus, pregnant women, difficulty with communication epidural catheter couldn't be inserted, inadequate epidural analgesia, dural puncture, patients unable to decide or unwilling to participate in the study, weight above 110kg, and height below 150 cm, were excluded. Patients were separated into Group $T_{6\text{-}7}$ and Group $T_{9\text{-}10}$ according to a computer-generated randomization list. 30 patients were assigned to each group.

2.2. Premedication and Anesthesia

The patients were monitored using the ASA standart protocol. All patients were premedicated with 0.05 mg/kg of midazolam and were given 2 L/min of oxygen via a face mask during epidural catheterization. 18 or 20 gauge intravenous (iv) catheters were placed on left and right arms for fluid and drug administration. 10 ml/kg of colloid infusion was initiated prior to catheterization for to prevent hypotension.

Epidural catheters were placed in the T6-7 and T9-10 intervertebral spaces. For this, midline approach and loss of resistance technique were used in sitting position in each group. Intravertebral spaces were examined with palpation to locate T_7 from where target intervertebral spaces were counted up or down. The skin was sterilized and draped in accordance with asepsis-antisepsis principals. Following skin infiltration with %1 lidocaine, an 18-gauge Tuohy epidural needle was progressed with the open bevel facing the cranial direction and a 20-gauge epidural catheter was progressed in cranial direction with 4 cm remaining in the epidural space.

A test dose of 1:200000 epinephrine and 2 ml of 1.5% lidocaine was administered, confirming no drug delivered into intrathecal or intravascular spaces. 10 ml of a solution of 0.1% of bupivacaine + 2.5 μg/kg fentanyl (4cc %0.5 Bupivacaine, 50 mcg Fentanyl, 15cc saline) was given in 1 ml doses every 10 seconds. Sensorial block was assessed by pinprick or cold/hot differentiation test. Analgesia was defined as loss of sensation of a pinprick or the cold of ice.

Lower extremity motor block was evaluated with the Bromage scale (0= no block, 1=able to move ankle and knees, no hip movement 2=able to move only ankle, no movement in hips or knees, 3= complete block). Upper extremity motor block was evaluated with finger grip movement (C_8/T_1), wrist (C_8/C_7) and elbow flexion (C_6/C_5) (ESSAM score 0= all three movements normal, 1= no finger grip but can perform other movements, 2= only elbow flexion elbow, 3=no movement).

Evaluations were repeated every 5 minutes after the first 30 minutes following TEA. Sensory block of T_6T_7 dermatomes was adequate for induction of surgical analgesia. Analgesia at these dermatomes was evaluated every minute until sensory block was established. The above-mentioned solution was given in 5ml aliquots every 5 minutes until block was achieved in these dermatomes.

ESSAM and Bromage scores, extent of the sensory block were recorded.

2.3. Hemodynamic Parameters

Mean arterial pressure (MAP), systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate, and SPO_2 were recorded before TEA. These recordings were repeated every 5 minutes after 30 minutes of TEA and every 10 minutes after sedation.

5 mg of iv ephedrine was given if a drop of more than

30% in SBP was observed or if SBP was < 90 mmHg. 1 mg of iv atropine was given if heart rate was<55 bpm. Following adequate block and 30 minutes after placement of a thoracic epidural catheter, anesthesia was induced with 0.3 mg/kg etomidate, 0.6 mg/kg rocuronium bromide and 2 μg/kg fentanyl. Anesthesia was maintained with %6 desflurane, %50 oxygen of dry air and 5 ml of the above-mentioned solution. All patients underwent pulmonary function tests with a hand spirometer 30 minutes before surgery (T_0) and at postoperative 6th (T1) and 24th hours (T2) in a sitting position. The pulmonary function tests (Forced vital capacity (FVC), expiratory volume at 1 second (FEV1), forced and FEV1 / FVC (FEV1 %)) were recorded. Testing was concluded in case of patient exhaustion, unwillingness to continue the test or unsuccessful testing after 8 attempts. Postoperative analgesia was achieved with a 15 cc solution with 3 mg of morphine, 50 mcg of fentanyl, and 11 cc of saline. Any postoperative complications of nausea, vomiting, or itching were recorded, as well as time to ambulation, recovery of gastrointestinal motility, and length of hospital stay.

2.4. Statistical Analysis

Sample size was calculated by G -* power that 29 patients should be included in the study at 80% power and 95% confidence interval in order to find a significant 15% decrease in systolic blood pressure between the two groups.

Statistical analysis was carried out with IBM SPSS version 20 software. Descriptive statistics with mean, median, standard deviation, minimum-maximum, number, and percentages were presented. Normal distribution of continuous variables was tested with the Shapiro-Wilk test. Comparison of two independent groups was carried out with independent samples t-test for normal distributions and Mann Whitney U test otherwise. For 2x2 categorical variables with expected values > 5 Pearson Chi-squared, with expected values 3-5 Chi-squared with Yates correction, and with expected values <3 Fisher's Exact test was applied. P values <0.05 were accepted as statistically significant.

3. Results

In total, 60 patients were included into the study (30 parturients in each group) (Figure 1).Demographic and operative data of patients and their ASA scores are presented in Table 1. The two groups were not statistically different for their demographic and operative properties. (p>0.05). Distribution of patients by type of operation is shown in Table 2.

Table 1: Demographic and operative data of patients.

	Group T6-7 (n=30)	Group T9-10 (n=30)	p
Age	69±4	68±3	0.817
Weight (kg)	71±11	70±10	0.763
Height (cm)	164±8	166±5	0.510
Gender (M/F)	16/14	15/15	0.796
BMI	25.68±3.33	25.28±4.37	0.273
ASA Score (I/II)	10/20	12/18	0.592
Operative Time (min)	175±39	199±48	0.140

All values are presented as mean ± standard deviation (SD) or numerical values. M:Male, F:Female, ASA: American Society of Anesthesiologists, BMI: Body Mass Index p>0.05.

Table 2: Distribution of patients by operation type.

	Group T6-7 (n=30)	Group T9-10 (n=30)		p
Stomach Cancer (n)	13	11	0.167	0.683
Cholecystectomy(n)	8	10	0.222	0.637
Choledocolithiasis(n)	2	3	0.200	0.655
Liver Hydatid Disease (n)	3	2	0.200	0.655
Liver Mass (n)	2	1	0.333	0.564
Cholangiocellular Canser (n)	1	1	0.000	1.000
Operative time (min)	1	2	0.333	0.564

All values are numerical values p>0.05.

Table 3: Highest and lowest dermatome level of analgesia and number of segments with block, and time to recovery of bowel sounds, time to ambulation and length of hospital stay.

	Group T6-7 (n=30)	Group T9-10 (n=30)	P
Highest dermatomal level with analgesia	T3 (T1-T5)	T4 (T1-T5)	0.033*
Lowest dermatomal level with analgesia	T12 (T9-L1)	L1 (T10-L2)	0.023*
Number of segments with block	9±3	9±2	0.517
Time to recovery of bowel sounds (h)	25.00 (12.00-62.00)	36.00 (23.00-96.00)	0.003*
Time to ambulation (h)	20.00 (8.00-48.00)	23.00 (11.00-48.00)	0.480
Length of hospital stay (days)	14.50 (14.50-27.00)	16.00 (5.00-39.00)	0.009*

All values are presented as mean±standard deviation (SD) or numerical values. *p<0.05 between T6-7 and T9- 10 groups.

Table 4: Respiratory Function Test results at different measurement times.

		Group T6-7 (n=30)	Group T9-10 (n=30)	p
FVC (L)	T0	2.30 (1.77-3.39)	2.15 (1.15-4.09)	0.515
	T1	1.36 (0.91-2.33)	1.25 (0.25-2.32)	0.028*
	T2	1.72 (1.32-3.26)	1.72 (0.97-2.92)	0.066
FEV_1(L)	T0	2.01(1.46-3.01)	1.81(1.06-3.67)	0.314
	T1	1.01(0.63-1.50)	1.04(0.20-1.38)	0.280
	T2	1.49 (0.93-2.25)	1.38 (0.62-2.41)	0.006*
FEV_1/FVC(%)	T0	88.50 (75.00-97.00)	87.00 (71.00-92.00)	0.312
	T1	77.00 (40.00-79.00)	79 (65.00-99.00)	0.004*
	T2	82.00 (70.00-98.00)	80.00 (63.00-85.00)	0.002*

All values are presented as median (min-max). T_0; Preoperative base value, T_1;Postoperative 6 hours T_2; Postoperative 24 hours. FVC: Forced Vital Capacity. FEV_1: Forced expiratory volume at 1 second. FEV_1/FVC(%): FEV percentage at 1 second *p<0.05 between T6-7 and T9-10 groups.

3.1 Hemodynamic findings

SBP, DBP, MAP, and heart rate of patients across time are graphed in Figures 2, 3, 4, and 5. SBP at 5th, 80th, and 90th minutes showed statistically significantly higer for T6-7 group compared T9-10 group (p=0.003, p=0.007, and p=0.013, respectively). At the same minute, DBP and MAP were statistically significantly higer in the T6-T7 group (p<0.001, p<0.001, p<0.001 and p=0.009, p<0.001, p<0.001, respectively) Heart rate was statistically significantly lower at 10th minutes (p<0.001) and statistically significantly higer at 60th, 80th, and 90th minutes (p<0.001, p=0.005, p=0.003, p<0.001 respectively) for T6-7 group than T9-10 group. No significant difference was detected for hemodynamic variables at other measurement points.

3.2. Dermatomal Spread

Highest and lowest dermatome levels and the number of segments with block are presented in Table 3. The groups did not differ in terms of the number of segments with block. (p>0.05). However, the groups differed significantly for highest and lowest dermatome levels with analgesia. (p=0.003 and p=0.023, respectively).

Table 5: ESSAM and BROMAGE scores of groups.

	Scores	Group T6-7 (n=30)	Group T9-10 (n=30)
ESSAM Score	0	30 (%100)	30 (%100)
	1	0(% 0)	0(% 0)
	2	0(% 0)	0(% 0)
	3	0(% 0)	0(% 0)
BROMAGE Score	0	30 (%100)	30 (%100)
	1	0(% 0)	0(% 0)
	2	0(% 0)	0(% 0)

Table 6: Nausea, Vomiting, and Itching in Study Groups.

		Group T6-7 (n=30)	Group T9-10 (n=30)	p
Nausea	Yes	18 (60.0%)	9 (30.0%)	0.020*
	No	12 (40.0%)	21 (70.0%)	
Vomiting	Yes	31 (0.0%)	9 (30.0%)	0.053
	No	27 (90.0%)	21 (70.0%)	
Itching	Yes	0 (0.0%)	4 (13.3%)	0.161
	No	30 (100.0%)	26 (86.7%)	

All values are presented as number and percentage. * p<0.05 significant between groups.

3.3. Time to Recovery of Gastrointestinal Motility, Time to Ambulation, and Length of Hospital Stay

Comparison of groups for time to recovery of bowel sounds, time to ambulation and length of hospital stay is given in Table 3. No statistically significant difference was observed for time to ambulation, (p>0.05) while time to recovery of gastrointestinal motility and length of hospital stay were statistically significantly shorter in the T6-7 group than other group (p=0.003 and p=0.009, respectively).

3.4. Pulmonary Function Test Results

Results of pulmonary function tests across groups are shown in Table 4. FVC did not differ between groups at T0 and T2 (p>0.05) while was statistically significantly higer for T6-7 group than T9-10 group at T1 (p=0.028). FEV1 did not differ between groups at T0 and T1 (p>0.05), while was statistically significantly higer at T2 in the T6-7 group (p=0.006). FEV1/FVC did not differ between groups at T0 (p>0.05) while was statistically significantly lower at T1 and statistically significantly higer at T2 in the T6-7 group than T9-10 group (p=0.004 and p=0.002, respectively).

3.5. ESSAM and BROMAGE Scores

ESSAM and BROMAGE scores of cases are summarized in Table 5. No motor block developed in either of the groups.

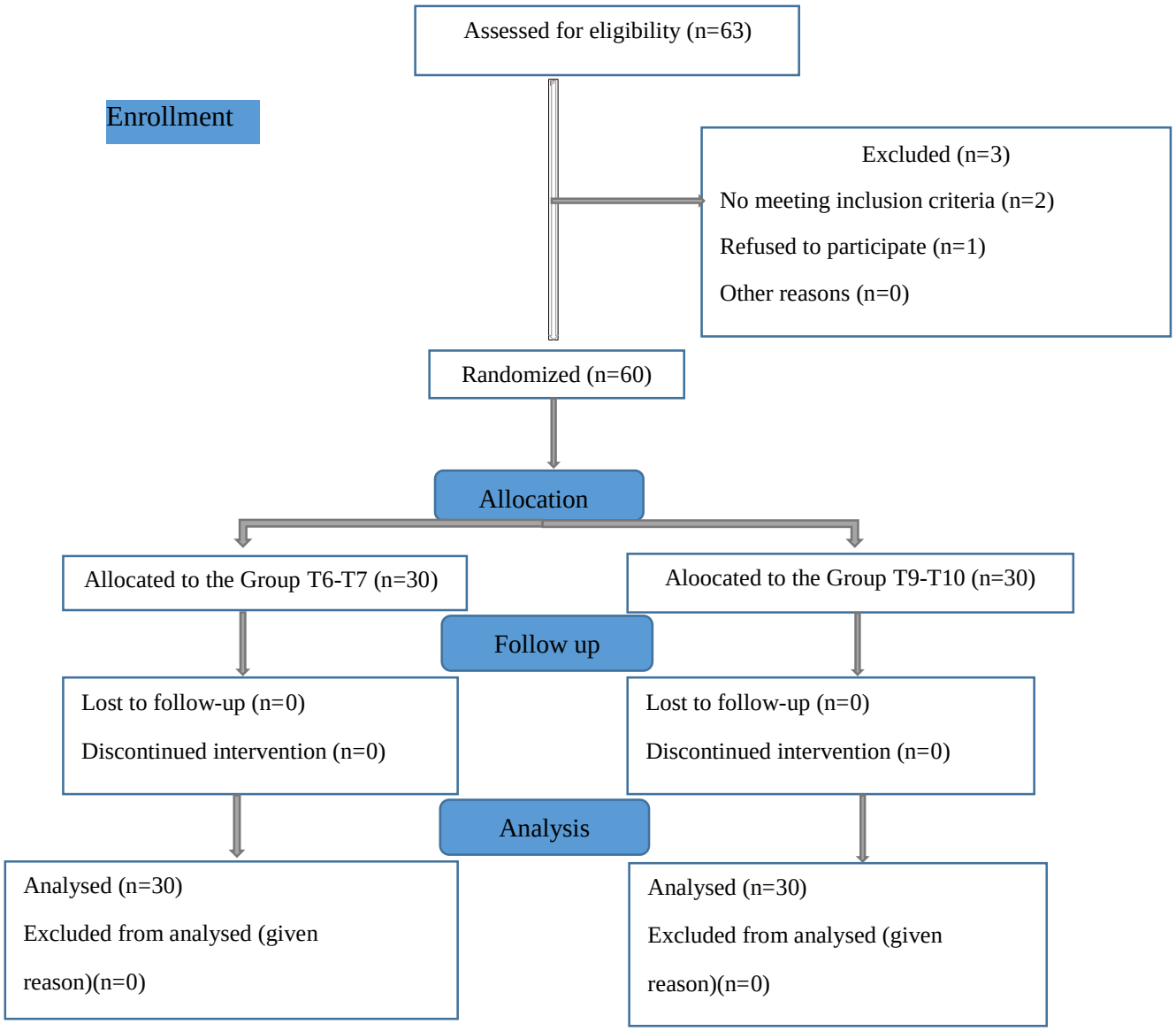

Figure 1: CONSORT flow diagram.

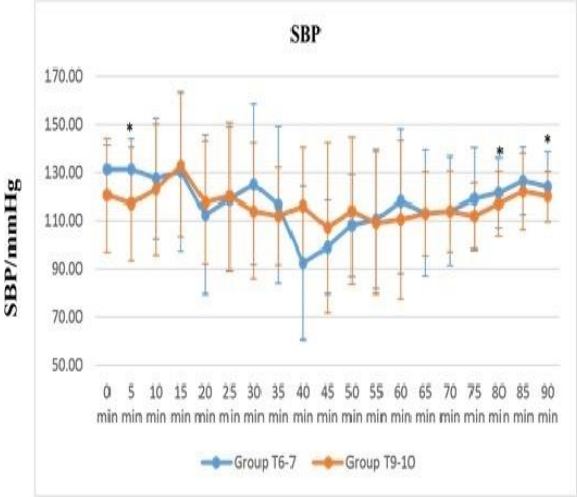

Figure 2: Change in systolic blood pressure across measurement times.
All values are presented as mean±standard deviation (SD) or numerical values. *p<0.05 between T6-7 and T9-10 group SBP: systolic blood pressure, min: minutes.

3.6. Nausea, Vomiting, and Itching

Cases with nausea, vomiting, and itching are presented in Table 6. While there was no statistically significant difference for vomiting and itching (p>0.05), there was statistically significantly difference for nausea between the two groups (p=0.02).

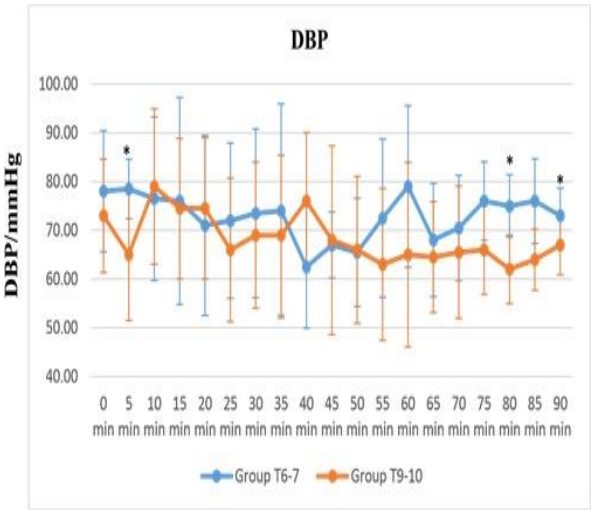

Figure 3: Change in diastolic blood pressure across measurement times.
All values are presented as mean±standard deviation (SD) or numerical values. *p<0.05 between T6-7 and T9-10 groups. DBP: diastolic blood pressure, min: minutes.

3.7. Atropine and Ephedrine Requirement

The groups did not differ in atropine or ephedrine requirement (p>0.05). 3 cases needed atropine and 7 needed ephedrine in Group T6-7 while no patients required atropine and 3 required ephedrine in Group T9-10.

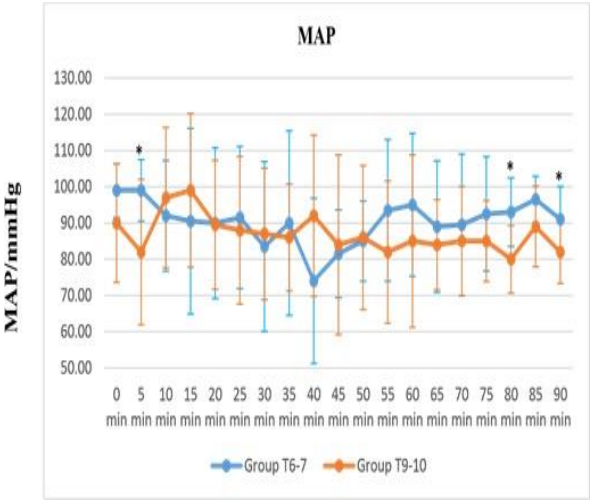

Figure 4: Change in mean arterial pressure across measurement times.
All values are presented as mean±standard deviation (SD) or numerical values**.** *p<0.05 between T6-7 and T9-10 groups, MAP; mean arterial pressure, min: minutes

Figure 5: Change in heart rate across measurement times.
All values are presented as mean ± standard deviation (SD) or numerical values. *p<0.05 between T6-7 and T9-10 groups. HR: heart rate, min: minutes.

4. Discussion

Our study demonstrated that TEA at a higher level resulted in a more stable hemodynamic response compared to lower level TEA. While higher level TEA resulted in a more profound drop in heart rate, it was associated with fewer cases of hypotension.

A study on patients aged 60 or above undergoing coronary artery bypass surgery compared a group receiving high thoracic epidural anesthesia (HTEA) at T_2-T_4 level with a group that did not receive TEA. Cardiac index, stroke volume index, central venous pressure, and central venous oxygen saturation were higher in the HTEA group. The authors also observed a lower MAP in the HTEA group with no difference in

heart rate. They concluded that HTEA positively affects cardiac performance in the elderly [6].

A study on 18 pigs compared epidural catheters at $L_{3/4}$ and $L_{4/5}$ levels. Catheters were proceeded to L_2 and T_2 under radioscopic guidance. Bupivacaine was administered for TEA and heart rate, MAP, SVR, right and left ventricular contractility were recorded. In the pigs with block at T_2, heart rate significantly dropped, with a minimal decrease in MAP and left ventricular contractility. In the pigs with block at L_2, MAP and SVR dropped significantly with a prominent rise in heart rate [7].

In our study, heart rate in the T_{6-7} group was significantly lower than in the T_{9-10} group at the 10th minute. In the first 15 minutes, heart rate was lower in the T_{6-7} group albeit insignificantly. We believe this decrease in heart rate is due to the increased block of cardiac sympathetic fibers at T_1-T_5 levels in the T_{6-7} group. The prominent decrease in SBP, DBP, and MAP in the T_{9-10} group can be explained by an increased block of sympathetic vasomotor fibers between T_5-L_1 levels. The level of sympathetic blockade is related to the area of drug distribution in the epidural space. We did not find a significant difference between groups in terms of atropine and ephedrine requirement.

No research has been conducted to compare atropine and ephedrine requirement across different levels of TEA. In a study on coronary artery bypass patients, no significant difference was reported for inotrope or vasoconstrictor requirement between patients who received HTEA and those who received no TEA [8]. Rectus abdominis, internal and external oblique, and transversus abdominis muscles contribute to respiration by maintaining abdominal support. Abdominal muscles are the primary muscles involved in forced respiration. TEA increases diaphragm activity by blocking inhibitory afferent fibers despite weakening respiratory intrathoracic respiratory muscles and intercostal musculature. The net effect is an increase in respiratory activity in patients undergoing upper abdominal surgery [9, 10]. In a study on TEA, block was performed to T_1-T_5 sensory dermatome levels and authors reported a drop of 5.6% in FVC and of 4.9% in FEV_1. These decreases in respiratory functions are explained by block of intercostal muscles [11, 12]. Another study compared two groups of TEA patients with block at C4-C7 and T_5-L_4 levels. FVC decreased by 25% in both groups, while FEV_1 decreased by 13% in the C4- C7 group and by

12% in the T5-L4 group [13]. Our results outline better respiratory functions when TEA was applied at T_{6-7} than at T_{9-10}. We believe this to be caused by an increased block of abdominal muscles in the T_{9-10} group.

Intestinal contractility is mediated by hormonal and neural factors. Parasympathetic activity increases gastrointestinal motility while sympathetic activity decreases it. In a study on patients undergoing major abdominal surgery under TEA, the number of segments with block at and above T_{12} level corresponded with faster reversal of gastrointestinal functions.[14, 15] Reversal of gastrointestinal motility was faster in the T_{6-7} group of our study which we associated with the increased extent of thoracic segments blocked in this group.

A study on patients operated for primary gastrointestinal malignancies compared a group receiving TEA with general anesthesia with another group receiving only general anesthesia. The group with TEA had a significantly shorter length of stay resulting from fewer cases of gastrointestinal system disorders.[16] The effect of different levels of TEA on length of hospital stay is not reported in prior research. Our results revealed a significantly shorter length of stay in the T_{6-7} group. We believe the faster return of gastrointestinal motility and better respiratory functions contribute to the shorter length of stay in this group.

5. Conclusion

In conclusion, TEA at a higher level resulted in a lesser drop in heart rate and blood pressure while atropine and ephedrine requirements did not differ between groups. The groups did not differ in terms of the number of segments with block but highest and lowest dermatome levels with analgesia were significantly differed between the group T6-7 and T9-10. The ambulation times of the groups were similar. Motor block did not develop in any patient. Nausea was detected in more patients in the T6-7 group. There was no difference between the groups in terms of nausea and itching. Higher TEA was beneficial as it allowed better hemodynamics, respiratory functions, gastrointestinal motility and shorter length of stay compared to lower TEA.

Limitations of the Study

We have some limitations in our study. Invasive hemodynamic measurements could provide more precise hemodynamic monitoring for cardiac index, stroke volume index, and SVR. However, invasive hemodynamic monitoring is not routinely practiced in our clinic and was not utilized in our study patients. Additionally, patients were not evaluated fluid responsiveness preoperatively. Our study was conducted in the geriatric patient group. Controlled hypertension patients were also included in our study. Studies can be planned in different patient groups. Sample size was calculated according to blood pressure change further studies can be planned with a larger sample size.

Acknowledgement

None.

Conflict of Interests

The authors declare that there is no potential conflict of interest for the research, authorship, and/or publication of this article. All authors read and approved the final manuscript.

Financial Support

The authors have no sources of funding to declare for this manuscript.

Author Contributions

Design of the study: AK, AD Sample collection: AK, SMC, Data Collection and/or Processing: AK, SMC, Writing Original Manuscript: AK, II, MA, AD. AK contributed to revising the work and final approval of the final version of the manuscript.

Ethical Approval

This study was approved by the Atatürk University Faculty of Medicine Clinical Research Ethics Committee (05/04-24.04.2014).

Data sharing statement

The data that support the findings of this study are available on request from the corresponding author.

Consent to participate

Consent was obtained from the patients participating in the study.

Informed Statement

The patient and control group who agreed to participate in the study signed the informed consent form.

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