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Erector spinae plane block combined with general anaesthesia versus conventional general anaesthesia in lumbar spine surgery

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ABSTRACT

Background: Perioperative pain management should be planned preoperatively and based on usage of pharmacological and non-pharmacological modalities as a multimodal analgesia (MMA). Regional anaesthesia has superior advantages than opioid-based anaesthesia and is one of the cornerstones of the Enhanced Recovery After Surgery (ERAS) especially in Patients undergoing spine surgery having already troublesome chronic pain and analgesic use. The present study was carried out to compare erector spinae plane block (ESP) with general anaesthesia versus conventional general anaesthesia in lumbar spine surgery.

Materials and Methods: This study was done on thirty adult patients of both sexes scheduled for elective lumbar spine surgery under general anaesthesia. They were randomly categorized into two equal groups (fifteen patients each); ESP was used for group I, and MMA was used for group II. Data was collected on anaesthetic requirements based on entropy monitoring and haemodynamic parameters, stress response measurement based on serum cortisol and blood glucose levels, controlled hypotensive anaesthesia; various drugs required and doses given, intraoperative and postoperative analgesia, postanaesthesia care unit data concerning recovery.

Results: The group I (ESP) had statistically significant decrease of the response and the response-state entropy difference levels when compared to the group II (MMA) after stimulus and during the 1st time interval. The incidence of hemodynamic changes was significantly higher in the group I (ESP) than group II (MMA). Only the serum cortisol but not the blood glucose levels had statistically significant lower mean values 4 h postoperatively in group I (ESP) compared to group II (MMA). The patients received ESP had statistically significant lower mean expired isoflurane concentration, decreased emergence time, intraoperative fentanyl consumption and total dose of pethidine given up to 8 hrpostoperatively.

Conclusions: Erector spinae plane block (ESP) can be considered safe and effective perioperative analgesic modality for lumbar spine simple decompression surgery. It helps in controlled hypotensive anaesthetic technique and decreases inhalational anaesthetics and intraoperative opioid requirements.

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Erector spinae plane block (ESP); multimodal analgesia (MMA)

1. Introduction

The rates of surgical procedures are increasing all over the world for acute low back pain, particularly for spinal fusion in patients with no specific back pain together with motor function weakness, or signs and symptoms of cauda equina syndrome. There is an increased incidence of complications and thus general considerations should be taken in most major spine surgeries and it is important that the patient is well oriented to them and is realistic about the surgical outcome. Blood loss, wound infection, and postoperative respiratory complications commonly occur. There is frequent need for blood transfusion even with the routine use of blood conservation stratigies like haemodilution or antifibrinolytic drugs. The spectre of spinal cord injury and motor affection needs to be raised: the incidence is ~ 1% in corrective spinal deformity surgery [1].

Perioperative pain management should be planned preoperatively and based on usage of pharmacological and non-pharmacological modalities. Multimodal analgesia includes variable analgesic techniques that aim to act in the peripheral and central nervous system so that more effective pain relief could be achieved instead of depending on single modality intervention so haemodynamic parameters can be controlled without opioids based anaesthesia. MMA may include NMDA antagonists, NSAID, alpha-2 agonists (clonidine and dexmedetomidine) and regional anaesthetic techniques [2].

Regional anaesthesia has superior advantages than opioid-based anaesthesia as it provides better pain relief, less nausea and vomiting, earlier return of the bowel function and better abolishment of the stress response and thus more controlled haemodynamic parameters [3].

There are many novel techniques developed and have been promising for perioperative pain control following major orthopaedic and spine surgeries; local continuous infusion devices consisting of elastomeric pump with flow restrictor connected to catheter,

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the wound infiltration with local anaesthetic drugs is a good pain control and may be beneficial in decreasing fibroblasts overgrowth and inflammatory mediators [4]. Injectable liposomal bupivacaine (ILB) is an another modality of the perioperative pain management. It is administered as a single dose into the surgical wound for postoperative analgesia as it requires no catheter, pump, or additional device. It can decrease pain and opioid consumption during the perioperative period [5].

Erector spinae plane block (ESP) is a new interfascial block with many potential clinical uses. It can be performed by superficial or deep needle approach, with the drug is injected above or

below the erector spinae muscle respectively. It is recommended to use the deep needle approach whereas the drug spreads craniocaudally closer to costotransverse foramina and origin of dorsal and ventral rami. It may spread to the intervertebral foramina to the origin of spinal nerves [6].

The erector spine plane block targeting the dorsal rami thus can be used as a perioperative pain control technique in lumbar spine surgeries [7]. It is applied preoperatively before skin incision as a preemptive analgesia so it suppresses chronic sensitization process. In addition, it may abolish the neuroendocrine stress response by decreasing release of the counter-regulatory hormones like catecholamines the mechanism by which it may augment controlled hypotensive anaesthesia [8]

The present study was carried out to compare erector spinae plane block combined with general anaesthesia versus conventional anaesthetic technique in lumbar spine.

2. Materials and methods

The study was carried out in Alexandria Main University Hospitals on 30 adult patients scheduled for elective lumbar spine surgical procedures under general anaesthesia.

2.1. Exclusion criteria

Patients were excluded if they met one of the following criteria:

1. Coagulation disorders.
2. BMI > 30 or < 18
3. Patients with surgical site infection.
4. Patients with unstable spine integrity like fractures or scoliosis.

4.Hypertensive, cardiac and diabetic patients.

After approval of The Local Ethical Committee and having an informed written consent from every patient, patients were randomly categorized into two equal groups (15 patients each) by closed envelope method:

Group I (ESP): The erector spinae plane block (ESP) was combined with general anaesthesia.

Group II (MMA): Conventional general anaesthesia receiving multimodal analgesia (MMA).

All patients included in this study, were assessed thoroughly by detailed medical and surgical history takin, complete clinical examination, routine laboratory investigations (complete blood picture, renal function tests, coagulation profile and fasting blood sugar). All patients were informed about the technique applied and any possible complications. On arrival in the operation room: a multi-channel monitor (GE Healthcare, Helsinki, Finland) was attached to the patient to display entropy monitoring, continuous ECG monitoring, heart rate (HR), Mean arterial blood pressure (MAP), arterial oxygen saturation (SaO2%) and anaesthetic gas analysis.

An intravenous line was secured and a venous sample was withdrawn for baseline serum cortisol level and baseline blood glucose level was checked then lactated Ringer's solution was started at 5 ml/kg/h. Ten minutes prior to induction of anaesthesia, all patients were premedicated by intravenous midazolam 0.02 mg/kg. Patients were preoxygenated with 100% oxygen for 3 minutes. In both groups (I) and (II), induction of anaesthesia was carried out by intravenous administration of fentanyl 1 µg/kg, lidocaine 1.5 mg/kg and propofol 2 mg/kg. After loss of verbal communication, 0.5 mg/kg atracurium was administrated. Controlled ventilation was provided via face mask with 100% O_2 and isoflurane (1–2%) for 3 min. Subsequently, endotracheal intubation achieved and intermittent positive pressure ventilation were adjusted to maintain an end-tidal carbon dioxide partial pressure between 30 and 35 mmHg. Anaesthesia was maintained with 1.5–2% isoflurane targeting expired isoflurane concentration 1.2% by the anaesthetic gas analyzer to ensure similar alveolar concentrations of inhalational anaesthetic in all patients. Also based on state entropy which is a measure of the current cortical state, adequate depth of anaesthesia was reached before surgical stimulus.

In group (I), after prone positioning and before surgery, the erector spinae plane block was performed bilaterally using a low-frequency-curved ultrasound transducer (Mindray

35C50EB, China) placed in a longitudinal orientation 3 cm lateral to the spinous process one vertebral level above a predetermined marked surgical incision. An 8-cm 22-gauge block needle (EchoStim; Benlan Inc, Oakville, Canada) was inserted in a cephalad-to-caudad direction until the tip lay in the interfascial plane below erector spinae muscle, the block was performed by injection of 20 mL of 0.25% bupivacaine. In group (II), ketorolac 0.75 mg/kg and paracetamol 10 mg/kg were given intravenously before surgical stimulus. In both groups (I) and (II), fentanyl 1 µg/kg as a rescue

analgesia was given based on entropy monitoring and haemodynamic parameters. During surgical dissection, systolic blood pressure 20–30% below baseline (80–90 mmHg in normal patients) was maintained using, in sequence if needed, propranolol 1 mg dose and if necessary, a second dose may be given after 2 min to keep heart rate < 80 beat/min, then increased concentration of volatile gas, and finally continuous infusion of glyceryl trinitrate (1–10 µg/kg/min).

If the mean arterial blood pressure has fallen below 50 mmHg, ephedrine 5 mg was administered and an intravenous bolus of 0.5 mg atropine was administered in case of bradycardia. The blood pressure was returned to the baseline value before surgical field closure. Then at the end of surgery, isoflurane vaporizer was shut off and muscle relaxant was reversed with neostigmine 0.04 mg/kg and atropine 0.02 mg/kg. The tube was removed after the patient regained consciousness, breath spontaneously and responded to verbal command.

The following parameters were measured:

1. Anaesthetic requirements

based on entropy monitoring parameters including state entropy

(a measure of the current hypnotic cortical state), response entropy (an indirect measure of

Adequacy of analgesia) and response – state entropy difference.

2. Haemodynamic parameters

a. Heart rate: beats per minute.

b. Arterial blood pressure: Mean Arterial Blood Pressure (MABP) will be measured in mmHg.

These parameters were monitored continuously and recorded at the following times: Before the induction of anaesthesia, after the induction of anaesthesia and before the erector spinae plane block, after the erector spinae plane block and the start of surgical stimulus, at 30 min intervals throughout the surgery, at end of anaesthesia, at eye opening.

3. Stress response measurement based on serum cortisol and blood glucose levels as a baseline value before induction of anaesthesia, postoperatively after recovery and 4 h after recovery.

4. Agents of controlled hypotensive anaesthesia: Infusion rate of glyceryl trinitrate using syringe pump (1–10 µg/kg/min, propranolol consumption (mg), expired isoflurane concentration (%).

5. Surgical area bleeding score: minimal bleeding: not a surgical nuisance, mild bleeding: but does not affect dissection, moderate bleeding: compromises dissection severe bleeding: significantly compromises dissection, massive bleeding: prevents dissection.

6. Intraoperative data: including emergence time (min): time from end of anaesthesia delivery till full recovery state, atropine dose (mg), ephedrine dose (mg) and Fentanyl dose (µg)

7. Postanaesthesia care unit data: Time to modified aldrete score > 9, postoperative analgesia using visual analogue scale (VAS) at time intervals 1, 2, 4, 8 h postoperatively, time to first analgesic requirements (min) based on reaching the score of 4 VAS where a rescue analgesia 0.5 mg/kg pethidine will be given intravenously, total dose of pethidine given (mg).

2.2. Statistical analysis

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp). Qualitative data were described using number and per cent. The Kolmogorov-Smirnov test was used to verify the normality of distribution Quantitative data were described using range (minimum and maximum), mean, standard deviation and median. Significance of the obtained results was judged at the 5% level.

The used tests were:

3. Chi-square test for categorical variables, to compare between different groups

2. Fisher's Exact or Monte Carlo correction: Correction for chi-square when more than 20% of the cells have expected count less than 5.

3. Student t-test: For normally distributed quantitative variables, to compare between two studied groups.

4. Mann–Whitney test: For abnormally distributed quantitative variables, to compare between two studied groups.

4. RESULTS

All thirty patients completed the study. There was no difference between the two groups with respect to demographic data Table1 Figure 1,2,3.

Comparing the two groups together concerning the entropy monitoring, there was not any statistically significant difference between both groups regarding state entropy mean values, Table 2c Figure 4. For group I (ESP), the response entropy mean values were 58.47 ± 8.81, 56.47 ± 6.46 after stimulus and first-time interval respectively, while for group II (MMA), the response entropy mean values were 64.40 ± 5.77, 61.53 ± 5.74 at the same time intervals. So, there were statistically significant differences between the t666wo groups after stimulus and at the first time interval (p values 0.039, 0.031) respectively Table3c Figure 5. Again, for group I (ESP), the response-state entropy difference mean values were 9.93 ± 2.99, 8.93 ± 2.91 after stimulus and first-time interval respectively, while for group II (MMA), the response entropy mean values were 16.60 ± 7.07, 13.93 ± 5.22 at the same time intervals. So, there were statistically significant differences between the two groups after

Table 1. Comparison between the two studied groups according to demographic data.

	Age		Gender		BMI	
Case no.	ESP	Multimodal	ESP	Multimodal	ESP	Multimodal
1	42	52	Male	Female	28	27.5
2	52	33	Male	Male	29.5	30
3	48	51	Female	Female	26	27
4	39	32	Male	Male	25	24
5	36	45	Male	Male	25.5	26
6	35	36	Male	Male	28	27.5
7	20	54	Male	Female	29.5	28
8	44	31	Female	Male	26	27.5
9	50	58	Female	Female	25	26
10	58	30	Male	Male	28	27
11	37	47	Male	Male	25	26
12	32	34	Male	Male	24	25
13	33	52	Male	Female	24.5	29
14	29	23	Male	Male	28	26
15	48	52	Female	Female	29	28
Min. Max. Mean	20.0	23.0	M = 11(73.3%)	M = 9(60.0%)	24.0	24.0
±SD.	58.0	58.0	F = 4(26.7%)	F = 6(40.0%)	29.50	30.0
	40.20	42.0			26.73	26.97
	10.0	11.09			1.91	1.53
Test of sig.	$t = 0.467$		$x^2 = 0.600$		$t = 0.370$	
p	0.644		0.439		0.714	

t: Student *t*-testx^2: **Chi-square test**
p: *p* value for comparing between the two groups

Table 2a. Change in state entropy in ESP group.

	State						
Cases no.	Before induction	After induction	After stimulus	First time interval	Second time interval	End of anaesthesia	At eye opening
1	90	57	63	54	59	80	90
2	85	59	40	42	43	78	90
3	92	75	39	40	36	54	91
4	91	60	51	56	60	70	88
5	89	57	61	55	57	77	89
6	86	55	42	42	44	75	91
7	91	73	40	40	36	54	91
8	92	61	50	56	59	70	88
9	92	55	61	52	59	80	90
10	85	60	43	42	45	79	90
11	91	72	44	43	40	58	90
12	92	62	53	58	61	70	88
13	86	55	60	50	56	82	86
14	92	59	40	42	43	78	90
15	91	77	41	41	39	55	90
Min.	85.0	55.0	39.0	40.0	36.0	54.0	86.0
Max.	92.0	77.0	63.0	58.0	61.0	82.0	91.0
Mean	89.67	62.47	48.53	47.53	49.13	70.67	89.47
±SD.	2.74	7.73	9.02	6.95	9.67	10.36	1.41

Table 2b. Change in state entropy in multimodal group.

	state						
Cases no.	Before induction	After induction	After stimulus	First time interval	Second time interval	End of anaesthesia	At eye opening
1	89	66	43	51	44	75	82
2	87	60	42	42	42	71	92
3	90	77	39	42	39	54	90
4	92	56	52	55	55	70	89
5	88	58	60	52	58	75	87
6	88	55	45	45	47	71	91
7	90	70	40	42	39	58	90
8	94	60	52	52	56	68	89
9	86	57	61	49	51	81	90
10	85	62	43	46	41	78	91
11	90	69	47	49	48	59	90
12	91	61	52	53	60	72	88
13	88	53	60	53	52	84	89
14	91	60	40	42	46	75	89
15	89	75	41	41	39	55	89
Min.	85.0	53.0	39.0	41.0	39.0	54.0	82.0
Max.	94.0	77.0	61.0	55.0	60.0	84.0	92.0
Mean	89.20	62.60	47.80	47.60	47.80	69.73	89.07
±SD.	2.34	7.26	7.83	4.97	7.22	9.30	2.31

Table 2c. Comparison between the two studied groups according to state entropy.

	State						
	Before induction	After induction	After stimulus	First time interval	Second time interval	End of anaesthesia	At eye opening
ESP							
Min.	85.0	55.0	39.0	40.0	36.0	54.0	86.0
Max.	92.0	77.0	63.0	58.0	61.0	82.0	91.0
Mean	89.67	62.47	48.53	47.53	49.13	70.67	89.47
±SD.	2.74	7.73	9.02	6.95	9.67	10.36	1.41
Multimodal							
Min.	85	53	39	41	39	54	82
Max.	94	77	61	55	60	84	92
Mean	89.2	62.6	47.8	47.6	47.8	69.73	89.07
±SD.	2.34	7.26	7.83	4.97	7.22	9.3	2.31
t	0.502	0.049	0.238	0.030	0.428	0.260	0.572
p	0.620	0.961	0.814	0.976	0.672	0.797	0.572

t: Student *t*-test
p: *p* value for comparing between the two groups

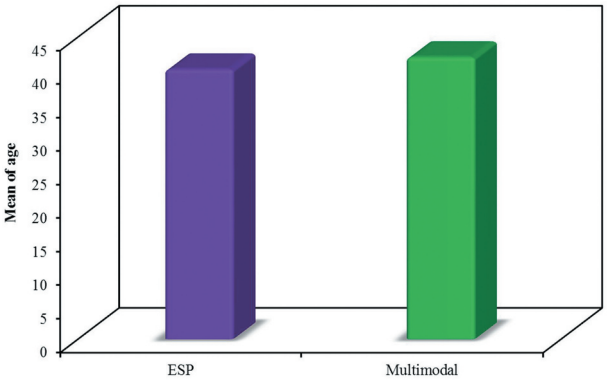

Figure 1. Comparison between the two studied groups according to age.

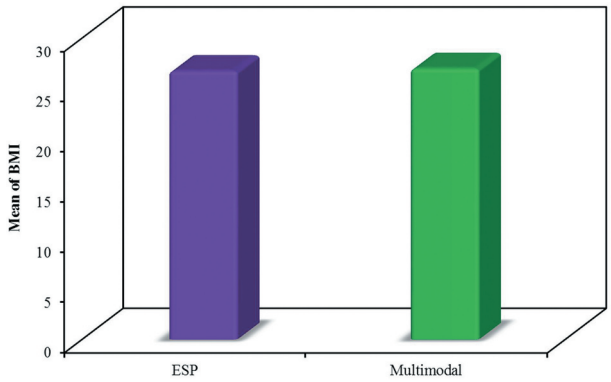

Figure 3. Comparison between the two studied groups according to BMI.

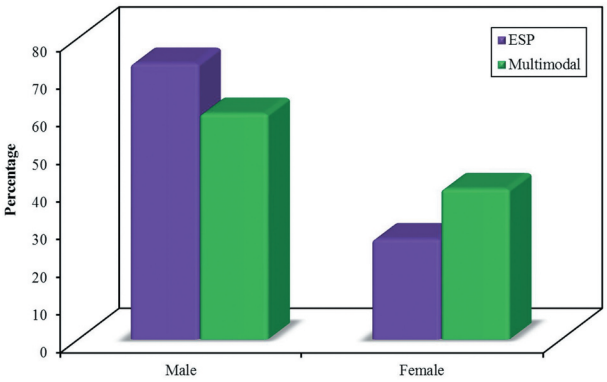

Figure 2. Comparison between the two studied groups according to gender.

stimulus and at the first time interval (*p* values 0.003, 0.004) respectively, Table4c Figure 6.

For group I (ESP), the mean heart rate values were 79.20 ± 12.46 and 74.0 ± 8.79 beats/min after stimulus and first-time interval respectively, while for group II (MMA), the mean heart rate values were 88.07 ± 10.22, 81.00 ± 8.03 beats/min at the same time intervals. So, there were statistically significant differences between the two groups after stimulus and at the first time interval (*p* values 0.042, 0.031) respectively Table5cFigure 7. For group I (ESP), the mean arterial blood pressure values were 84.73 ± 7.12 mmHg after stimulus, while for group II (MMA), the mean arterial blood pressure values were 92.53 ± 11.56 mmHg at the same time interval. So, there was a statistically significant difference between the two groups after stimulus, Table 6c Figure 8.

Stress response measurement based on serum cortisol and blood glucose levels were measured as a baseline value before induction of anaesthesia, postoperatively after recovery and 4 h after recovery. As regards group I (ESP) 4 h postrecovery time, the mean serum cortisol was 18.69 ± 8.21 ug/dl, while in group II (MMA), it was 30.50 ± 16.25 ug/dl. There was a statistically significant difference between the two groups (Pcortisol = 0.040). In contrary to that, there were no statistically significant differences between the two groups regarding the mean serum cortisol values (Table 7c, Figure 9) and the mean serum sugar values (Table 8c, Figure 10) in preoperative and postoperative times.

Agents of controlled hypotensive anaesthesia were used. The number of group I (ESP) patients received glyceryl trinitrate infusion and propranolol consumption, was fewer than the number of group II (MMA) patients; however, there was no significant difference (Tables 9 and 10, Figures 11 and 12) respectively. While the mean expired isoflurane concentration in group I ESP patients was statistically lower 1.44 ± 0.17% than that in group II (MMA) patients 1.64 ± 0.28%

Table 3a. Change in response entropy in ESP group.

	Response						
Cases no.	Before induction	After induction	After stimulus	First time interval	Second time interval	End of anaesthesia	At eye opening
1	100	63	69	59	62	84	94
2	98	68	47	49	53	85	96
3	95	89	52	52	48	67	98
4	99	69	66	66	68	79	98
5	99	64	68	59	62	85	95
6	99	66	48	50	52	83	98
7	95	87	52	53	48	65	98
8	100	72	63	66	68	80	98
9	100	62	69	59	66	85	96
10	97	68	53	49	56	89	99
11	95	87	55	56	51	68	98
12	100	70	66	68	68	80	98
13	99	63	69	58	62	88	95
14	99	68	47	49	53	85	96
15	99	88	53	54	49	66	99
Min.	95.0	62.0	47.0	49.0	48.0	65.0	94.0
Max.	100.0	89.0	69.0	68.0	68.0	89.0	99.0
Mean	98.27	72.27	58.47	56.47	57.73	79.27	97.07
±SD.	1.87	10.06	8.81	6.46	7.70	8.44	1.58

Table 3b. Change in response entropy in multimodal group.

	Response						
Cases no.	Before induction	After induction	After stimulus	First time interval	Second time interval	End of anaesthesia	At eye opening
1	99	71	54	63	58	88	91
2	100	68	52	52	51	80	98
3	95	89	55	55	51	68	97
4	99	65	66	66	66	79	98
5	99	65	71	59	66	84	94
6	99	66	55	55	59	82	98
7	95	84	51	53	50	70	98
8	100	70	65	64	66	80	98
9	96	65	70	58	59	88	96
10	97	70	53	56	52	88	100
11	95	82	57	58	59	68	98
12	100	70	63	63	68	80	98
13	97	62	70	62	60	89	99
14	98	68	49	52	56	84	97
15	99	86	50	52	50	67	99
Min.	95.0	62.0	49.0	52.0	50.0	67.0	91.0
Max.	100.0	89.0	71.0	66.0	68.0	89.0	100.0
Mean	97.87	72.07	58.73	57.87	58.07	79.67	97.27
±SD.	1.88	8.69	7.91	4.79	6.35	7.86	2.22

Table 3c. Comparison between the two studied groups according to response entropy.

	State						
	Before induction	After induction	After stimulus	First time interval	Second time interval	End of anaesthesia	At eye opening
ESP							
Min.	95.0	62.0	47.0	49.0	48.0	65.0	94.0
Max.	100.0	89.0	69.0	68.0	68.0	89.0	99.0
Mean	98.27	72.27	58.47	56.47	57.73	79.27	97.07
±SD.	1.87	10.06	8.81	6.46	7.70	8.44	1.58
Multimodal							
Min.	95.0	62.0	53.0	52.0	50.0	67.0	91.0
Max.	100.0	89.0	71.0	70.0	68.0	89.0	100.0
Mean	97.87	72.07	64.40	61.53	58.07	79.67	97.27
±SD.	1.88	8.69	5.77	5.74	6.35	7.86	2.22
t	0.584	0.058	2.183*	2.271*	0.129	0.134	0.284
p	0.564	0.954	0.039*	0.031*	0.898	0.894	0.778

t: Student *t*-test
p: *p* value for comparing between the two groups

(Piso = 0.025) Table11 Figure 13. There was no statistically significant difference between the two groups as regards surgical area bleeding score (*p* value = 0.547). For group I (ESP), surgeons feedbacked minimal bleeding with two patients (13.3%), mild bleeding with eight patients (53.3%), moderate bleeding with five patients (33.3%) and no severe bleeding at all (0.0%), while for group II (MMA), they feedbacked mild bleeding with nine patients (60.0%), moderate bleeding with six patients (40.0%) and no minimal or severe bleeding

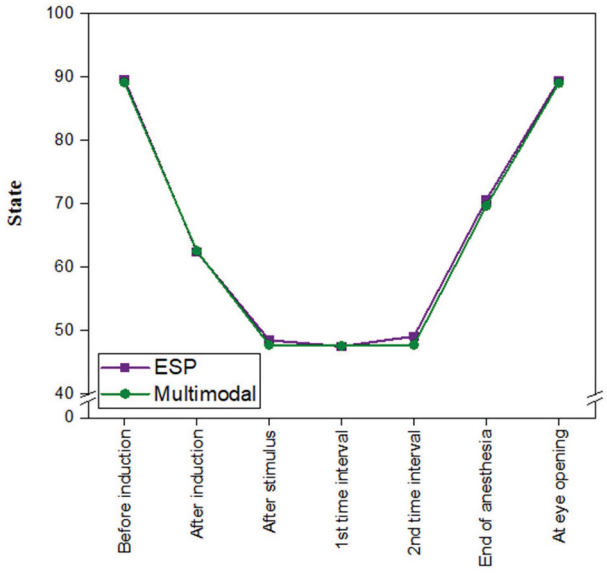

Figure 4. Comparison between the two studied groups according to state entropy.

at all (0.0%). There was no statistically significant difference between the two groups as regards surgical area bleeding score (p value = 0.547) (Table 20, Figure 22).

Regarding intraoperatively administered drugs, group I (ESP) patients (six patients 40%) received statistically significant higher mean ephedrine dose 5.33 ± 6.94 mg, compared to that in group II (MMA) patients (Pephedrine = 0.007) (Table 13, Figure 15). Also, fentanyl consumption was statistically lower in group I (ESP) patients (two patients, 13.3%, 10.0 ± 28.03 µg) when compared to that in group (MMA) II (eight patients, 53.3%, 46.67 ± 48.06 µg) (Pfentanyl = 0.049) (Table 15, Figure 17). However, there was a statistically significant difference as regards the mean emergence time (12.13 ± 3.76, 15.73 ± 4.65 min) between the two groups respectively (p value = 0.021). In addition, no patients of either group received atropine intraoperatively (p value = 1.000) (Table 14 Figure 16).

Table 4a. Change in difference in ESP group.

	Difference						
Cases no.	Before induction	After induction	After stimulus	First time interval	Second time interval	End of anaesthesia	At eye opening
1	10	6	6	5	3	4	4
2	13	9	7	7	10	7	6
3	3	14	13	12	12	13	7
4	8	9	15	10	8	9	10
5	0	7	7	4	5	8	6
6	13	11	6	8	8	8	7
7	4	14	12	13	12	11	7
8	8	11	13	10	9	10	10
9	8	7	8	7	7	5	6
10	12	8	10	7	11	10	9
11	4	15	11	13	11	10	8
12	8	8	13	10	7	10	10
13	13	8	9	8	6	6	9
14	7	9	7	7	10	7	6
15	8	11	12	13	10	11	9
Min.	0.0	6.0	6.0	4.0	3.0	4.0	4.0
Max.	13.0	15.0	15.0	13.0	12.0	13.0	10.0
Mean	7.93	9.80	9.93	8.93	8.60	8.60	7.60
±SD.	3.94	2.78	2.99	2.91	2.64	2.47	1.84

Table 4b. Change in difference in multimodal group.

	Difference						
Cases no.	Before induction	After induction	After stimulus	First time interval	Second time interval	End of anaesthesia	At eye opening
1	10	5	11	12	14	13	9
2	13	8	7	10	9	9	6
3	5	12	16	13	12	14	7
4	7	9	14	11	11	9	9
5	11	7	11	7	8	9	4
6	11	10	10	10	12	11	7
7	5	14	11	11	11	12	8
8	6	10	13	12	10	12	9
9	10	8	9	9	8	7	6
10	12	8	10	10	11	10	9
11	5	13	10	9	11	9	8
12	9	9	11	10	8	8	10
13	9	9	10	9	8	5	10
14	7	8	9	10	10	9	8
15	10	11	9	11	11	12	10
Min.	5.0	5.0	7.0	7.0	8.0	5.0	4.0
Max.	13.0	14.0	16.0	13.0	14.0	14.0	10.0
Mean	8.67	9.40	10.73	10.27	10.27	9.93	8.0
±SD.	2.66	2.35	2.22	1.49	1.79	2.40	1.73

Table 4c. Comparison between the two studied groups according to response-state entropy difference.

	Difference						
	Before induction	After induction	After stimulus	First time interval	Second time interval	End of anaesthesia	At eye opening
ESP							
Min.	3.0	6.0	6.0	4.0	3.0	4.0	4.0
Max.	13.0	15.0	15.0	13.0	12.0	13.0	10.0
Mean	8.60	9.80	9.93	8.93	8.60	8.60	7.60
±SD.	3.29	2.78	2.99	2.91	2.64	2.47	1.84
Multimodal							
Min.	5.0	5.0	9.0	7.0	8.0	5.0	6.0
Max.	13.0	14.0	31.0	23.0	14.0	14.0	10.0
Mean	8.67	9.47	16.60	13.93	10.27	9.93	8.20
±SD.	2.66	2.39	7.07	5.22	1.79	2.40	1.37
t	0.061	0.352	3.364*	3.241*	2.023	1.497	1.011
p	0.952	0.727	0.003*	0.004*	0.053	0.146	0.321

t: Student *t*-test
p: *p* value for comparing between the two groups

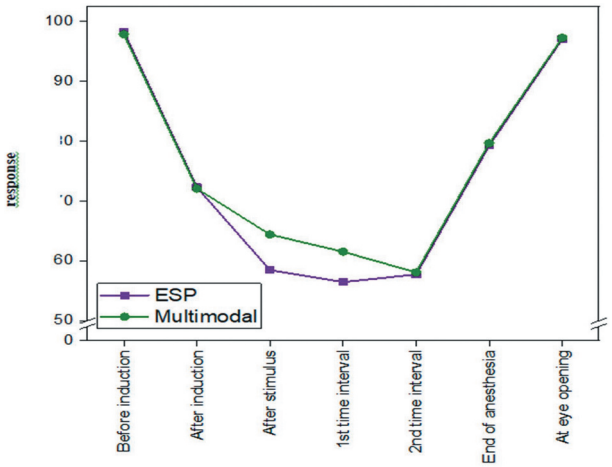

Figure 5. Comparison between the two studied groups according to response entropy.

In PACU, time to modified aldrete score > 9 was measured and showed slightly higher value though not significant in group I (ESP) patients in comparison to group II (MMA) patients (22.13 ± 4.50, 20.0 ± 5.49 min) respectively (*p* value = 0.054) (Table 16, Figure 18). postoperative pethidine analgesic consumption 2 h postsurgery was statistically lower in group I (ESP) patients (8.33 ± 12.20 mg) than that in group II (MMA) (18.33 ± 11.44 mg) (*p* value 0.031) (Table 18c, Figure 20), additionally, total dose of pethidine given was statistically lower in group I (ESP) patients (16.67 ± 12.20 mg) than that in group II (MMA) (30.0 ± 10.35 mg) (*p* value 0.029) (Table19, Figure 21), whereasthere was no significant difference regarding time to first analgesic requirements (min) based on reaching the score of 4 VAS as well as the pethidine consumption at any other postoperative time intervals (Table17, Figure 19).

4.1. Discussion

The rates of surgical procedures are increasing all over the world for acute low back pain, particularly for spinal fusion in patients with no specific back pain together with motor function weakness, or signs and symptoms of cauda equina syndrome. The National Institute for Health and Clinical Excellence (NICE) held a committee for considering recommendations to monitor the depth of anaesthesia in the NHS in England, the Bispectral Index (BIS) was recommended as anaesthesia depth monitor option to reduce the

Table 5a. Change in heart rate (beats/min) in ESP group.

	Heart rate (beats/min)						
Cases no.	Before induction	After induction	After stimulus	First time interval	Second time interval	End of anaesthesia	At eye opening
1	80	90	86	78	77	91	107
2	91	91	99	91	88	98	90
3	81	87	85	79	74	78	93
4	84	91	61	64	60	81	103
5	100	95	89	71	69	74	80
6	90	72	75	73	87	92	79
7	72	82	78	67	73	75	87
8	80	81	74	71	62	90	80
9	85	93	89	81	80	94	110
10	89	88	96	88	85	95	87
11	82	88	86	80	75	79	94
12	85	90	60	63	59	80	101
13	100	93	59	64	60	79	101
14	83	74	76	75	88	92	80
15	70	79	75	65	70	72	82
Min.	70.0	72.0	59.0	63.0	59.0	72.0	79.0
Max.	100.0	95.0	99.0	91.0	88.0	98.0	110.0
Mean	84.80	86.27	79.20	74.0	73.80	84.67	91.60
±SD.	8.45	7.07	12.46	8.79	10.46	8.70	10.66

Table 5b. Change in heart rate (beats/min) in multimodal group.

	Heart rate (beats/min.)						
Cases no.	Before induction	After induction	After stimulus	First time interval	Second time interval	End of anaesthesia	At eye opening
1	77	85	74	75	80	92	107
2	69	69	75	58	60	68	70
3	94	88	77	78	79	88	94
4	85	87	90	75	85	94	95
5	95	98	98	83	85	92	99
6	83	103	106	92	80	82	89
7	77	78	78	73	78	90	105
8	76	70	77	60	63	69	73
9	88	78	65	76	77	86	92
10	86	89	91	76	86	91	96
11	98	95	95	80	81	90	96
12	88	101	105	93	82	83	90
13	71	77	70	71	77	89	103
14	70	75	78	62	65	73	75
15	89	90	79	73	76	89	92
Min.	69.0	69.0	65.0	58.0	60.0	68.0	70.0
Max.	98.0	103.0	106.0	93.0	86.0	94.0	107.0
Mean	83.07	85.53	83.87	75.0	76.93	85.07	91.73
±SD.	9.33	10.83	12.70	10.07	8.03	8.49	11.20

Table 5c. Comparison between the two studied groups according to heart rate.

	Heart rate (beats/min.)						
	Before induction	After induction	After stimulus	First time interval	First time interval	End of anaesthesia	At eye opening
ESP							
Min.	70.0	72.0	59.0	63.0	59.0	72.0	79.0
Max.	100.0	95.0	99.0	91.0	88.0	98.0	110.0
Mean	84.80	86.27	79.20	74.0	73.80	84.67	91.60
±SD.	8.45	7.07	12.46	8.79	10.46	8.70	10.66
Multimodal							
Min.	69.0	69.0	75.0	68.0	60.0	68.0	70.0
Max.	98.0	103.0	106.0	97.0	86.0	94.0	107.0
Mean	83.07	85.53	88.07	81.0	76.93	85.07	91.73
±SD.	9.33	10.83	10.22	8.03	8.03	8.49	11.20
t	0.533	0.220	2.131*	2.277*	0.92	0.127	0.033
p	0.598	0.828	0.042*	0.031*	0.365	0.899	0.974

t: Student *t*-test
p: *p* value for comparing between the two groups

adverse outcomes. Also, the committee described the clinical uses for the E-Entropy to evaluate the response of patient under anaesthesia to a stimulus in addition to monitoring the depth of anaesthesia [4].

Ode et al investigated how to monitor efficacy of a regional block, monitoring was either to test onset and readiness for surgery as a sole block or evaluation of block under general anaesthesia. In the later one, they

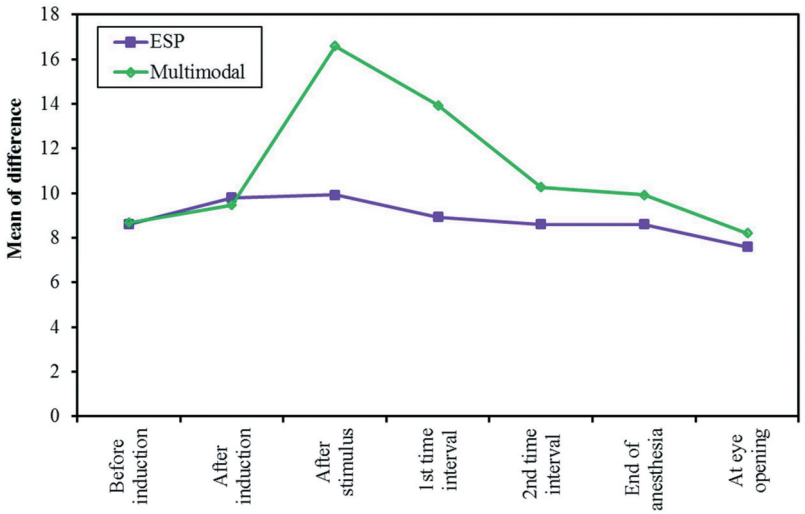

Figure 6. Comparison between the two studied groups according to entropy difference.

Table 6a. Change in mean arterial blood pressure in ESP group.

	Mean arterial blood pressure (mmHg)						
Cases no.	Before induction	After induction	After stimulus	First time interval	Second time interval	End of anaesthesia	At eye opening
1	112	80	88	60	75	100	96
2	99	91	93	89	90	99	91
3	97	107	74	68	76	76	104
4	114	100	80	75	79	93	85
5	107	76	93	64	60	83	97
6	88	70	84	70	64	93	91
7	98	89	88	81	79	85	80
8	88	79	87	88	87	90	90
9	115	78	86	58	73	98	94
10	105	93	95	91	92	101	93
11	99	104	70	65	73	72	100
12	116	105	78	73	77	90	84
13	106	80	90	68	64	86	100
14	89	69	83	69	62	92	90
15	99	86	82	79	77	82	78
Min.	88.0	69.0	70.0	58.0	60.0	72.0	78.0
Max.	116.0	107.0	95.0	91.0	92.0	101.0	104.0
Mean	102.13	87.13	84.73	73.20	75.20	89.33	91.53
±SD.	9.59	12.58	7.12	10.43	9.79	8.68	7.45

Table 6b. Change in mean arterial blood pressure in multimodal group.

	Mean arterial blood pressure (mmHg)						
Cases no.	Before induction	After induction	After stimulus	First time interval	Second time interval	End of anaesthesia	At eye opening
1	105	102	110	79	85	110	110
2	103	90	77	73	73	100	107
3	113	103	74	70	67	100	110
4	100	73	87	73	84	92	105
5	91	75	93	79	76	78	98
6	104	88	100	75	93	86	105
7	108	105	105	83	88	113	114
8	100	87	77	70	71	97	103
9	111	107	69	69	67	98	108
10	99	69	79	70	80	88	102
11	97	78	95	84	79	82	100
12	101	85	97	72	90	83	102
13	110	108	110	88	90	115	115
14	92	84	78	68	70	95	100
15	114	113	69	73	74	102	110
Min.	91.0	69.0	69.0	68.0	67.0	78.0	98.0
Max.	114.0	113.0	110.0	88.0	93.0	115.0	115.0
Mean	103.20	91.13	88.0	75.07	79.13	95.93	105.93
±SD.	7.08	14.23	14.39	6.13	8.80	11.30	5.19

Table 6c. Comparison between the two studied groups according to mean arterial blood pressure.

	Mean arterial blood pressure (mmHg)						
	Before induction	After induction	After stimulus	First time interval	Second time interval	End of anaesthesia	At eye opening
ESP							
Min.	88.0	69.0	70.0	58.0	60.0	72.0	78.0
Max.	116.0	107.0	95.0	91.0	92.0	101.0	104.0
Mean	102.13	87.13	84.73	73.20	75.20	89.33	91.53
±SD.	9.59	12.58	7.12	10.43	9.79	8.68	7.45
Multimodal							
Min.	91.0	69.0	69.0	68.0	67.0	78.0	98.0
Max.	114.0	113.0	110.0	88.0	93.0	115.0	115.0
Mean	103.20	91.13	92.53	75.07	79.13	95.93	105.93
±SD.	7.08	14.23	11.56	6.13	8.80	11.30	5.19
t	0.346	0.816	2.225*	0.598	1.157	1.793	6.141*
p	0.732	0.422	0.034*	0.556	0.257	0.084	<0.001*

t: Student *t*-test
p: *p* value for comparing between the two groups
*: Statistically significant at $p \leq 0.05$

used processed EEG versions like entropy indices that change values with nociceptive stimuli in relatively small observational studies, but up till now, no publications described using entropy indices for evaluation of anaesthesia of spine surgery [9].

In parallel to that, we evaluated the anaesthetic requirements and the response to noxious stimuli by using state and response entropy indices respectively for both groups studied. The above-mentioned values suppose that ESP combined with general anaesthesia

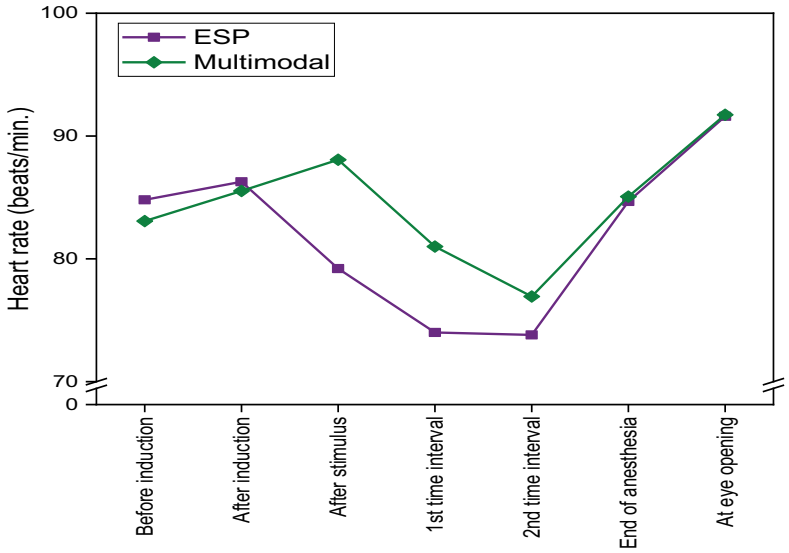

Figure 7. Comparison between the two studied groups according to heart rate.

Table 7a. Change in serum cortisol in ESP group.

	Serum cortisol		
Cases no.	Baseline	Postoperative	4 h postrecovery
1	13.7	20.7	8.29
2	24.3	25.6	24.1
3	16.5	21.5	9.87
4	19.8	35.8	17.7
5	14.5	22.6	27.5
6	20.9	26.1	23.3
7	12.7	20.5	10.5
8	29.8	33.6	35.2
9	17.2	23.1	10.8
10	28	23.3	21.8
11	22	24	12.32
12	17.3	33.3	15.2
13	18	25.1	30
14	19.4	23.6	20.8
15	18.2	23	13
Min.	12.70	20.50	8.29
Max.	29.80	35.80	35.20
Mean	19.49	25.45	18.69
±SD.	4.91	4.84	8.21
Median	18.20	23.60	17.70

Table 7b. Change in serum cortisol in multimodal group.

	Serum cortisol		
Cases no.	Baseline	Postoperative	4 h postrecovery
1	21.1	27.9	31.1
2	17.6	17.2	5.28
3	22.4	39.4	60
4	30.9	27.8	18.4
5	20.9	20.8	38.5
6	12.6	13.8	4.45
7	16.6	25.4	28.6
8	20.1	19.7	7.8
9	17.9	36.9	57.4
10	24.9	24.8	15.4
11	20.9	23.6	41.3
12	10.1	11.3	4
13	20.1	27.8	31
14	15.4	33.3	48.2
15	28.4	27.3	18
Min.	10.10	11.30	4.0
Max.	30.90	39.40	60.0
Mean	19.99	25.13	27.30
±SD.	5.46	7.88	18.90
Median	20.10	25.40	28.60

Table 7c. Comparison between the two studied groups according to serum cortisol.

	Serum cortisol		
	Baseline	Postoperative	4 h postrecovery
ESP			
Min.	12.70	20.50	8.29
Max.	29.80	35.80	35.20
Mean	19.49	25.45	18.69
±SD.	4.91	4.84	8.21
Median	18.20	23.60	17.70
Multimodal			
Min.	10.10	11.30	10.28
Max.	30.90	39.40	60.0
Mean	19.99	25.13	30.50
±SD.	5.46	7.88	16.25
Median	20.10	25.40	28.60
U	125.0	119.0	162.0*
p	0.604	0.787	0.040*

U: Mann–nWhitney test
p: *p* value for comparing between the two groups

can help in alleviating painful stimuli during surgery evidenced by statistically significant lower mean response and response-state entropy differences than those of the group II (MMA).

Similarly, Seok et al reported fluctuating values of response/state entropy concomitant with increased heart rate and mean arterial blood pressure and everytime this would occur, rocuronium increments were given and RE/SE were normalized. This was repeated twice and the rising bouts of RE/SE ceased only after remifentanil infusion started. No more rocuronium was given although the TOF increased to 70 based on steady RE/SE indices. This explains how entropy indices greatly influenced by the degree of analgesia and may be falsely elevated by occasional EMG activity [10].

Opposite to that, Young et al presented a case study where they discontinued entropy monitoring and depended on the PSI values derived from Sedline monitor

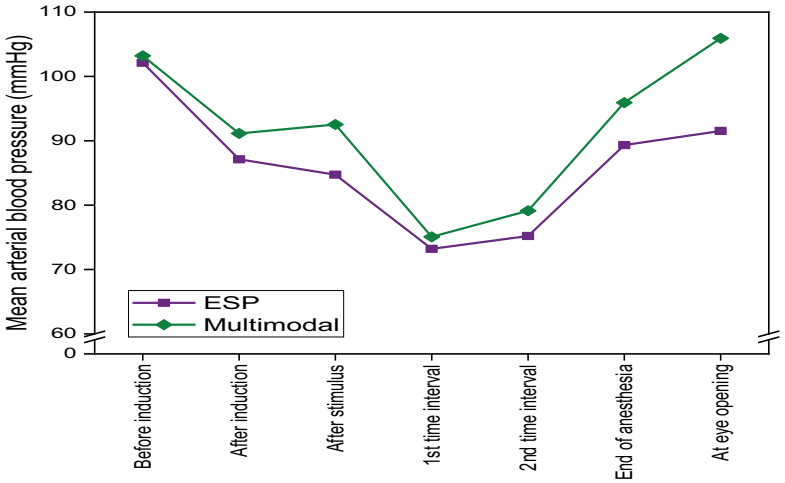

Figure 8. Comparison between the two studied groups according to mean arterial blood pressure.

Table 8a. Change in random blood sugar in ESP group.

	Random blood sugar		
Cases o.	Baseline	Postoperative	4 h postrecovery
1	89	134	105
2	92	145	100
3	101	171	119
4	99	158	95
5	82	124	88
6	88	139	90
7	79	123	85
8	94	148	99
9	105	158	101
10	100	161	122
11	82	144	80
12	77	112	89
13	90	151	92
14	85	133	89
15	118	166	111
Min.	77.0	112.0	80.0
Max.	118.0	171.0	122.0
Mean	92.07	144.47	97.67
±SD.	11.07	17.05	12.28

Table 8b. Change in random blood sugar in multimodal group.

	Random blood sugar		
Cases no.	Baseline	Postoperative	4 h postrecovery
1	93	140	100
2	99	158	103
3	90	138	98
4	104	179	120
5	82	138	89
6	85	148	93
7	80	133	90
8	95	150	93
9	86	167	105
10	108	182	118
11	98	136	85
12	79	129	90
13	93	155	96
14	88	122	84
15	107	177	102
Min.	79.00	122.00	84.00
Max.	108.00	182.00	120.00
Mean	92.47	150.13	97.73
±SD.	9.40	19.04	10.71

(masimo). They described increased EMG activity and rising RE/SE values associated with regular hammering the patient tibia and recommended assessment of the

Table 8c. Comparison between the two studied groups according to random blood sugar.

	Random blood sugar		
	Baseline	Postoperative	4 h postrecovery
ESP			
Min.	77.0	112.0	80.0
Max.	118.0	171.0	122.0
Mean	92.07	144.47	97.67
±SD.	11.07	17.05	12.28
Multimodal			
Min.	79.00	122.00	84.00
Max.	108.00	182.00	120.00
Mean	92.47	150.13	97.73
±SD.	9.40	19.04	10.71
t	0.107	0.859	0.016
p	0.916	0.398	0.987

t: Student *t*-test
p: p value for comparing between the two groups

two monitors as no artefacts would occur with double monitoring [11].

Another experienced implication was studied by Aho et al, they found inconsistent values recorded by entropy concomitantly with raw EEG signal during general anaesthesia, electrocautery-induced artefacts. episodic EMG activity revealed non-relevant BIS and entropy indices with the raw EEG signals [12].

Finally at the second time interval, the RE/SE difference values returned < 10 for almost all either group cases showed high difference values especially the significantly higher values in group II. We can explain this by once multimodal analgesic drugs are given, they require a reasonable time onset for their pharmacodynamic elicited response unlike the bupivacaine in group I (ESP).

This could be justified by what Keelara et al studied, they compared preemptive IV paracetamol and NSAID to IV paracetamol in lumbar spine surgery as regards morphine consumption. They stated drugs should be administered preemptively before induction so as to provide sufficient time for the onset of action [13].

The haemodynamic parameters are considered reliable clinical indicators for a balanced anaesthetic

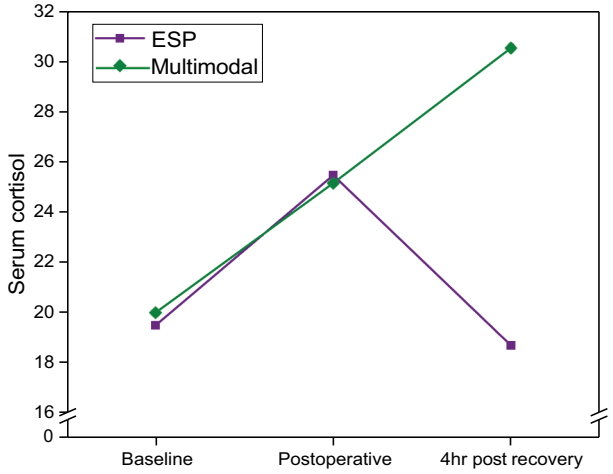

Figure 9. Comparison between the two studied groups according to serum cortisol.

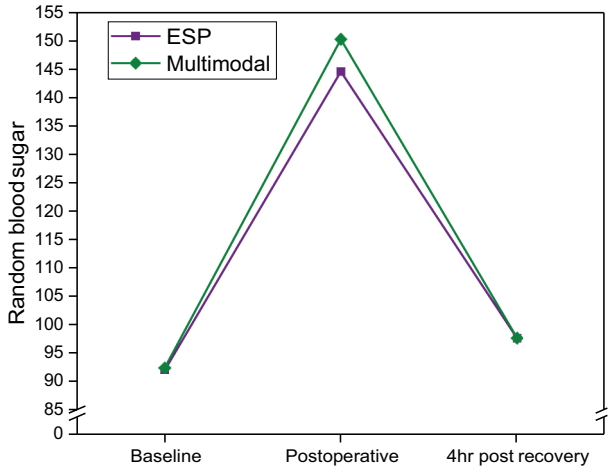

Figure 10. Comparison between the two studied groups according to random blood sugar.

technique and judgemental of the analgesic requirements. Unbalanced anaesthesia leads to unacceptable haemodynamic changes by aggravating the sympathetically induced stress response during certain steps like intubation, noxious stimulus and extubation [14].

Similarly, Vikram et al compared multimodal analgesia including local anaesthesia infiltration with conventional analgesic regimen mainly IV paracetamol in lumbar spine surgery as regards the haemodynamic responses to intubation, change of position and noxious surgical incision. They reported significantly lower mean heart rate in the study group after skin incision than the control group, the mean heart rate after surgical incision almost remained the same as before the stimulus [15]. The local anaesthesia wound infiltration could be as effective as the ESP maximally at the level of skin incision.

Masahiko also studied the advantages of combining regional anaesthesia namely transversus abdominis plane block with general anaesthesia in open abdominal surgery and found the heart rate would be 70 −110% of the preanaesthetic levels in much more surgery time than those levels in patients undergoing only general anaesthesia and concluded that these advantages can be obtained with other regional anaesthetic techniques [16].

Concomitantly to our clinical trial, Zhang et al just finished a trial comparing ESP and general anaesthesia regarding only the haemodynamic changes and opioid consumption, they found statistically significant lower mean values of both the heart rate and mean arterial blood pressure in patients received ESP than those underwent only general anaesthesia [17].

Table 9. Comparison between the two studied groups according to glyceryl trinitrate rate (µg/kg/min).

	Glyceryl trinitrate rate (µg/kg/min)	
Case no.	ESP	Multimodal
1	0	1
2	0	0
3	0	1
4	0	0
5	0	0
6	1	1
7	0	0
8	0	0
9	0	1
10	0	0
11	0	1
12	0	0
13	1	0
14	0	1
15	0	0
0	13 (86.7%)	9 (60.0%)
1	2 (13.3%)	6 (40.0%)
Min.	0.0	0.0
Max.	1.0	1.0
Median	0.0	0.0
U	142.50	
p	0.104	

U: Mann Whitney test
p: *p* value for comparing between the two groups

Table 10. Comparison between the two studied groups according to propranolol use (mg).

Case no.	Propranolol use (mg)		
	ESP		Multimodal
1	1		0
2	0		1
3	1		0
4	0		1
5	1		1
6	0		1
7	0		0
8	0		0
9	1		0
10	0		1
11	0		0
12	1		1
13	0		1
14	0		1
15	1		0
0	9 (60.0%)		7 (46.7%)
1	6 (40.0%)		8 (53.3%)
x2		0.536	
p		0.464	

x^2: Chi-square test
p: *p* value for comparing between the two groups

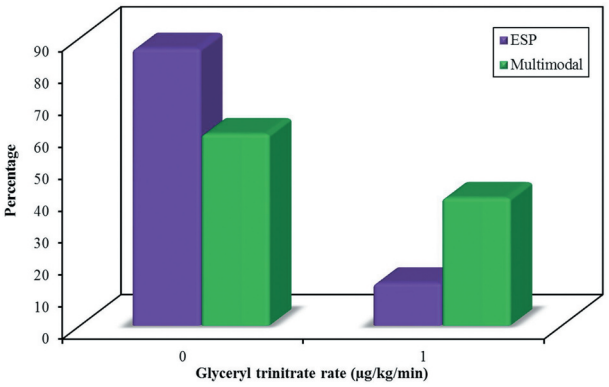

Figure 11. Comparison between the two studied groups according to Glyceryl Tri-nitrate infusion rate (GTN) (µg/kg/min).

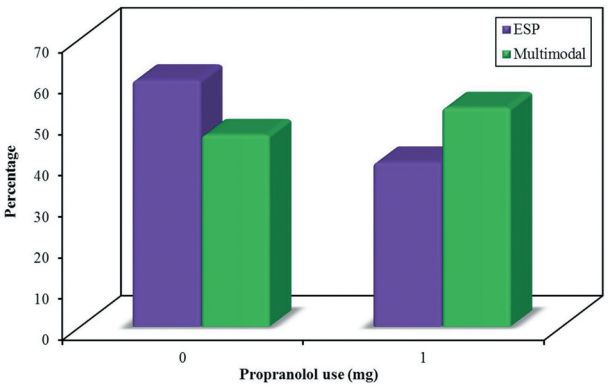

Figure 12. Comparison between the two studied groups according to propranolol use (mg).

Whenever during the first time and second intervals, the mean arterial blood pressure showed no statistically significant values between the two groups, it may be explained by what Gousheh et al documented; they thought that IV paracetamol has about 30–60 min onset of action and on giving after induction of anaesthesia, it may improve VAS-based pain evaluation [18]. compared to the bupivacaine given in ESP, it may act in a shorter time. Another probable factor existed and might contribute to the no significant mean arterial blood pressure which is the more consumption of hypotensive agents in Group II, it made the mean values in group II closer to their analogues in group I.

Stressful events can stimulate cardiovascular responses mainly resulting in increased heart rate and contractility also leads to neurohumoral influences by activating of the hypothalamic pituitary adrenal axis and increased cortisol secretion. It stimulates gluconeogenesis in the liver. In addition, by potentiating the effects of epinephrine, it elevates glycogenolysis in the liver, thus excess gluconeogenesis and glycogenolysis cause hyperglycemia [19].

To our best knowledge, the available studies about ESP in spine surgery did not assess the stress response during surgery based on hormonal parameters in a controlled clinical trial. The serum cortisol had statistically significant lower mean values 4 h postoperatively in group I (ESP) compared to group II (MMA) but there were no other statistically significant differences of the mean serum baseline cortisol levels and the postoperative levels.

Similarly, Kuchler et al evaluated the analgesic needs as well as the stress response in spine surgery based on the RBS and cortisol levels between postoperative epidurally administered levobupivacaine and administered saline placebo, the RBS did not have any significant different values despite the VAS score and the analgesic requirements mean values were statistically significant lower with the intervention group than the control group at the measured time intervals [20].

Again, Nermin et al found there were no significant increase of RBS levels between the three groups studied; morphine, low and high doses of

Table 11. Comparison between the two studied groups according to expired isoflurane mean concentration %.

	Expired isoflurane mean concentration%	
Case no.	ESP	Multimodal
1	1.4	2.1
2	1.2	1.5
3	1.4	2
4	1.2	1.2
5	1.5	1.7
6	1.7	2
7	1.5	1.5
8	1.5	1.4
9	1.4	2
10	1.3	1.5
11	1.3	1.8
12	1.4	1.4
13	1.8	1.5
14	1.4	1.6
15	1.6	1.4
Min. Max. Mean	1.20	1.20
±SD.	1.80	2.10
	1.44	1.64
	0.17	0.28
t	2.389*	
p	0.025*	

t: Student *t*-test
p: *p* value for comparing between the two groups
*: Statistically significant at $p \leq 0.05$

Table 12. Comparison between the two studied groups according to emergence time (min).

	Emergence time (min)	
Case no.	ESP	Multimodal
1	9	15
2	14	19
3	12	20
4	6	5
5	20	17
6	10	12
7	15	20
8	10	13
9	10	22
10	13	9
11	13	16
12	7	14
13	18	15
14	12	19
15	13	20
Min.	6.0	5.0
Max.	20.0	22.0
Mean	12.13	15.73
±SD.	3.76	4.65
Median	12.0	16.0
U	168.0*	
p	0.021*	

U: Mann–Whitney test
p: *p* value for comparing between the two groups

dexmedetomidine despite there were variable clinical responses regarding the VAS and Ramsy sedation score [21].

Ezhevskaya et al found decreased stress response in patients undergoing major spinal surgery when they received epidural analgesia rather than the control group. The patients received epidural analgesia had statistically significant lower blood cortisol and glucose levels [22].

Yoder et al also studied serial cortisol levels, at skin closure and every 2 h up to 6 h postoperatively as a stress response measuring tool to compare variable invasive surgical procedures, they reported greatest significant values at the end of surgery up to 2 h post-operatively correlated to how it was invasive and lengthy, but the subsequent 2 h intervals showed no significant differences [23].

Alessandro et al had a large meta-analysis included several studies about serum cortisol levels and stress reoponse in surgeries from grade I to III, total serum cortisol peaked around the time of extubation at the end of surgery (for grade II procedures like our surgical

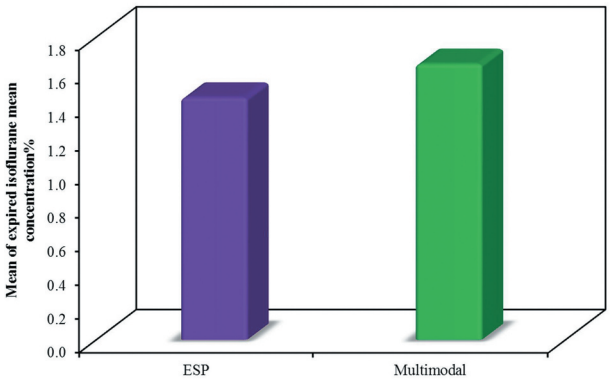

Figure 13. Comparison between the two studied groups according to expired isoflurane mean concentration %.

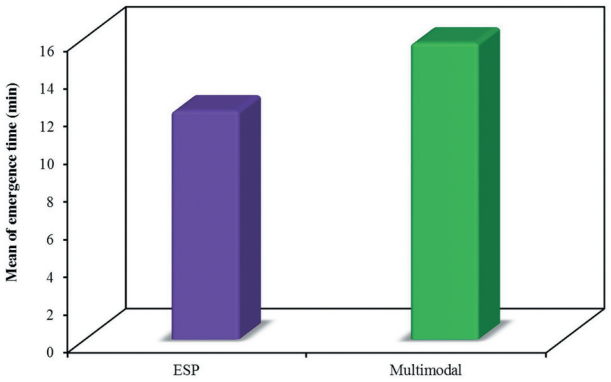

Figure 14. Comparison between the two studied groups according to emergence time (min).

technique) and revealed greatest Area Under The curve (AUC) till 6 h postoperatively in the first 24 h cortisol assay. Also, they evaluated the influences of the anaesthetic techniques on the stress response, there was lower AUC with regional anaesthetic techniques peaked at 6 h postoperatively [24].

PH (moderate level of controlled hypotension) usually refers to an intraoperative blood pressure (BP) decrease by about 20–30% of baseline values. Usually, it can be achieved by using a balanced anaesthetic technique rather than hypotensive drugs. Induced hypotension, on the other hand, commonly requires a higher level of controlled blood pressure decrease requiring titrated infusion of hypotensive drugs.

Soghomonyan et al conducted a survey that addresses the different techniques and principles of using permissive hypotension in neurosurgical practice. About 70.2% of anaesthesiologists maintained the SBP level above 90 mmHg. Less frequently (29.8% of anaesthesiologists), SBP target values <90 mmHg were used. When the mean arterial blood pressure (MABP) was used to control the level of hypotension, 70% of anaesthesiologists preferred maintaining the MABP ≥ 60 mmHg [25].

Similarly, the MABP levels for group I (ESP) were (73.20 ± 10.43), (75.20 ± 9.79) mmHg during the first- and second- time intervals respectively, while for group II (multimodal), they were (75.07 ± 6.13), (79.13 ± 8.80) mmHg during the same sequential time intervals respectively.

In our study, we started Glyceryl Trinitrate (GTN) infusion (1 µg/kg/min) and it could be satisfactory in controlling the MABP. For group I (ESP), only two cases had MABP as much as 90 mmHg that did not subside so far a while after surgical stimulus and needed GTN

Table 13. Comparison between the two studied groups according to ephedrine dose (mg).

	Ephedrine dose (mg)	
Case no.	ESP	Multimodal
1	15	0
2	0	0
3	0	0
4	15	0
5	0	0
6	10	0
7	0	0
8	0	0
9	15	0
10	0	0
11	0	0
12	15	0
13	0	0
14	10	0
15	0	0
Not received	9 (60.0%)	15 (100.0%)
Received	6 (40.0%)	0 (0.0%)
Min.	0.0	0.0
Max.	15.0	0.0
Mean	5.33	0.0
±SD.	6.94	0.0
Median	0.0	0.0
U	67.50*	
p	0.007*	

U: Mann–Whitney test
p: *p* value for comparing between the two groups
*: Statistically significant at $p \leq 0.05$

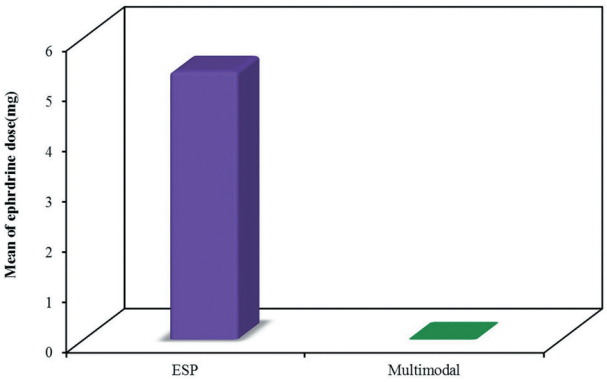

Figure 15. Comparison between the two studied groups according to ephedrine dose (mg).

infusion. On the other hand, for group II (MMA), six cases received GTN same infusion rate but it was not statistically significant difference.

Agreeing to that and concomitantly to our study, Li et al tested the efficacy of ESP in lumbar spine surgery and found more stable haemodynamic parameters without any aiding hypotensive drugs but the difference was statistically significant; the diastolic blood pressure and the HR were statistically lower with the ESP group rather than the control group (PDBP $< ^{0.001,\ P}$HR $= 0.003)$ [26].

Again, Brandao et al reported a case scheduled for lumbar spine surgery and received bilateral one-shot ESP preoperatively, they were satisfied with blunting the sympathetic stimulation and there was no need for hypotensive techniques [27].

Also, Timothy et al reported a rare complication with ESP given at high thoracic levels; harlequin syndrome which represents partial autonomic neuropathy, it resulted from spreading the block to the sympathetic ganglia and the postganglionic sympathetic fibers, it led to transient facial erythema, upper limb diaphoresis and concomitant hypotension. As a result, they supported the hypothesis that ESP is a paravertebral block so that it could contribute to controlled haemodynamic measurements [28].

Ghamry et al supported our hypothesis stating better control of haemodynamic parameters with ESP; they found statistically significant lower mean heart rate and MABP with the intervention group than the control group [29].

Concerning the expired isoflurane mean concentration %, the group I (ESP) participants had lower mean isoflurane concentration 1.44 ± 0.17% than its instance in group II (MMA)

1.64 ± 0.28% and the difference was statistically significant (PISO = 0.025)

Similarly, Ahiskalioglu et al performed ESP as a main anaesthetic for hip surgery, contrast MRI revealed local anaesthetic spread to ventral rami of both the lumbar and upper part of the sacral plexuses. They found ESP could be a main anaesthetic with minimal sedoanalgesia in terms of the least titratable propofol infusion [30].

Again, Forero et al performed ESP combined with general anaesthesia in a challenging case scenario where epidural analgesia was unsuitable due to previous extensive corrective surgery for scoliosis and previous opioid intake led to critical bronchospasm. They maintained anaesthesia with minimal anaesthetic requirements 0.4–0.7 MAC

Table 14. Comparison between the two studied groups according to atropine dose (mg).

	Atropine dose (mg)	
Case no.	ESP	Multimodal
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
9	0	0
10	0	0
11	0	0
12	0	0
13	0	0
14	0	0
15	0	0
Not received	15 (100.0%)	15 (100.0%)
Received	0 (0.0%)	0 (0.0%)
Min.	0.0	0.0
Max.	0.0	0.0
Mean	0.0	0.0
±SD.	0.0	0.0
Median	0.0	0.0
U	112.50	
p	1.000	

U: Mann–Whitney test
p: *p* value for comparing between the two groups

Table 15. Comparison between the two studied groups according to fentanyl dose (µg).

	Fentanyl dose (µg)		
Case no.	ESP		Multimodal
1	0		0
2	0		100
3	100		100
4	0		100
5	0		0
6	0		100
7	0		0
8	0		0
9	0		100
10	0		50
11	50		0
12	0		50
13	0		0
14	0		0
15	0		100
Not received	13 (86.7%)		7 (46.7%)
Received	2 (13.3%)		8 (53.3%)
Min.	0.0		0.0
Max.	100.0		100.0
Mean	10.0		46.67
±SD.	28.03		48.06
Median	0.0		50.0
U		159.5*	
p		0.049*	

U: Mann–Whitney test
p: *p* value for comparing between the two groups
*: Statistically significant at $p \leq 0.05$

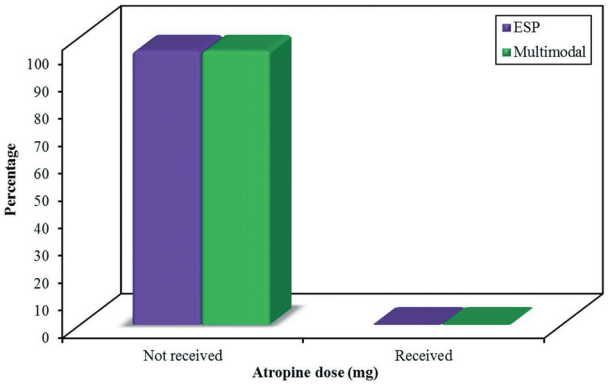

Figure 16. Comparison between the two studied groups according to atropine dose (mg).

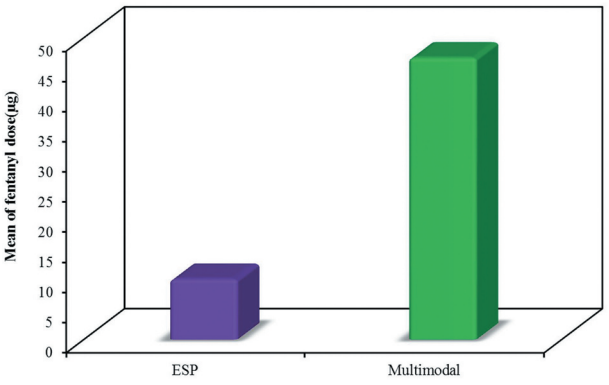

Figure 17. Comparison between the two studied groups according to fentanyl dose (µg).

desflurane and reported the case had the same quality and duration to what they experienced by patients underwent the most common anaesthetic technique performed there (general anaesthesia and epidural analgesia) [31].

For controlled haemodynamics, we used B-blocker propranolol to control any incompatible rise of the heart rate. And there was no statistical significant difference (Pprop = 0.464).

In parallel to that, isoflurane in higher concentrations can be used for inducing hypotension especially when used in a balanced anaesthetic technique but sometimes tachycardia, that may accompany its usage, leads to a less controlled hypotension ion and misjudge the adequacy of antinociception [32].

Aujla et al studied inhalational anaesthetic isoflurane for controlled hypotension compared to TIVA and used esmolol as a rescue drug to control the heart rate and reach the targeted mean arterial blood pressure. The group of isoflurane received more esmolol than the TIVA group as regards the number of the cases and may warrant for tachycardia-induced isoflurane but this was not statistically significant [33].

Daccache et al documented that haemodynamic parameters like tachycardia and hypertension had low sensitivity and specificity and were considered poor predictors of antinociception administration. Instead, objective monitoring of nociception/antinociception has been developed based on cortical (electroencephalographic) or subcortical (sympathetic – parasympathetic [pS] balance) derived signals. They found the Analgesia Nociception Index (ANI) more sensitive than pulse rate and mean blood pressure in detecting surgical noxious stimuli [34].

Table 16. Comparison between the two studied groups according to time to modified aldrete score > 9 (min).

	Time to modified aldrete score > 9 (min)	
Case no.	ESP	Multimodal
1	15	20
2	22	20
3	24	30
4	18	10
5	28	17
6	25	21
7	23	18
8	25	22
9	17	27
10	20	12
11	26	15
12	27	23
13	21	16
14	27	24
15	14	25
Min.	14.0	10.0
Max.	28.0	30.0
Mean	22.13	20.0
±SD.	4.50	5.49
t	1.164	
p	0.054	

t: Student *t*-test
p: *p* value for comparing between the two groups

Also, Weber et al suggested monitoring devices using other parameters, such as skin conductance, plethysmography, pupillometry and heart rate variability were more sensitive assessment of the nociception/antinociception balance than haemodynamic parameters [35].

Similarly, Ogiwara et al used propranolol in refractory tachycardia on reporting a case with refractory tachycardia and hypotension which was correlated later on with hyperthyroidism [36].

So the haemodynamic parameters such as the heart rate and the MABP may not be specific for maintaining nociception/antinociception balance.

Contrary to that, the heart rate and thus the extent using pulse limiting drugs were considered so far a golden standard clinical indicator of the adequacy of analgesia together with other clinical parameters like the blood pressure, sweating, lacrimation, pupillary reflex and movements [37].

Also, Farah et al studied the effect of labetalol when used in induced hypotension and suggested reduced labetalol dose in combination with more fentanyl increments, also they stated better induced hypotensive anaesthesia when clonidine was combined with remifentanil infusion [38].

Anaesthesia emergence time is the time taken from discontinuing administration of anaesthetic at the end of the surgical procedure till return of consciousness. Group I patients had statistically significant lower mean emergence time 12.13 ± 3.76 min when compared to that of the group II patients 15.73 ± 4.65 min (Pemergence = 0.021).

This was a reasonable finding that might be due to significant lower mean isoflurane concentration in group I patients. Also, they received significantly lower mean fentanyl dosage which may be another factor.

Disagreeing with that, Akihiro et al considered anaesthesia emergence time reflecting recovery of the whole central nervous system with many confounding factors rather than the anaesthetics administered, they stated mean end-tidal carbon dioxide during surgery (mETCO2), mean body temperature during surgery (mBT) were significant clinical factors of emergence time in ambulatory surgery [39].

In group I, patients had significantly lower mean fentanyl requirements 10 ± 28.03 μg when compared to group II patients 46.67 ± 48.06 μg (Pfentanyl = 0.049).

Josh et al studied ESP in six patients underwent lumbosacral spine surgery as case series; three lumbar discectomies, two sacral laminectomies, and one coccygectomy. They summarised that ESP played a crucial role in effective perioperative opioid-sparing analgesia in three cases while a catheter was inserted in the other three cases so prolonged the analgesic benefit and prevented escalating opioid dose [40].

Michael et al performed ESP in a case report study of two patients underwent corrective surgery for scoliosis. They adopted multimodal analgesia regimen in form of dexmedetomidine and ketamine infusion. They concluded ESP could be safe and effective opioid-sparing analgesic strategy [41].

Chin et al similarly reported a case study of redo corrective scoliosis surgery that had ESP as an analgesic strategy, the patient had satisfied analgesia at the PACU rather than the intolerable side

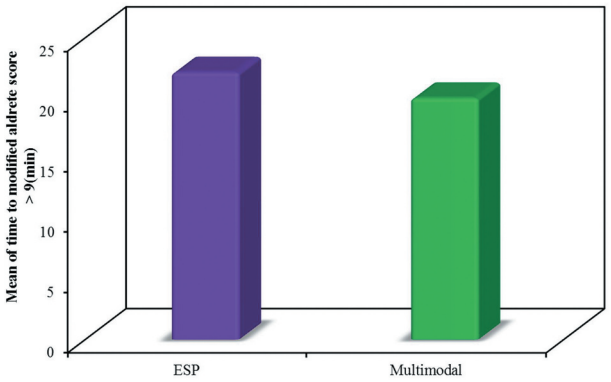

Figure 18. Comparison between the two studied groups according to time to modified aldrete score > 9 (min).

effects and escalating doses of opioids consumed in the previous surgery [42].

Goyal et al described a case report of cervical spine fixation surgery due to C6 vertebral body fracture and disc prolapse that received preoperative bilateral ESP at C7 transverse process, the surgery continued 9 h and no rescue additional opioids were required based on controlled haemodynamic parameters [43].

Ghamry et al studied intraoperative fentanyl consumption in general anaesthesia based on ESP as an analgesic strategy, they found mean fentanyl consumption (75.5 ± 5.99 µg) in the intervention group compared to its analogue (298.2 ± 16.3 µg) in the control group. The difference was statistically significant (Pfentanyl < 0.001) and they concluded effective acute pain management of lumbar spine surgery with bilateral one-shot ESP [29].

Contrary to that, Zhang et al studied the range of area covered by ESP, they performed ESP in twelve cases and mapped the skin area blocked by ESP by cold sensory stimuli, the block did not extend to the lateral chest or anterior abdominal wall suggesting that only the dorsal branches of the spinal nerves but not the ventral branches were blocked [44].

Thus, the sinuvertebral nerve which arises from the ventral rami could be spared, it supplies both proprioceptive and nociceptive fibres to many structures of middle and anterior columns of the spine such as the pedicle, anterior and posterior longitudinal ligaments, intervertebral discs and vertebral end plate surfaces. That is why ESP may be adequate analgesic strategy for lumbar spine simple decompression but not for spine vertebral body interfusion [45].

Regarding ephedrine consumption, six patients in group I (40%) received ephedrine while nine patients (60%) did not receive and they had totally statistically significant higher mean ephedrine increments (mg) (5.33 ± 6.94) than group II patients where no cases received ephedrine dosage (0.0) (^{f}Pephedrine = 0.007). The significant decrease of the MABP and subsequent significant increase of ephedrine administration, to our best knowledge, had two explainations; either masking the stress response as regional anaesthetic technique or precipitating hypotension as paravertebral block could result in.

Similar speaking about regional anaesthesia, Janssen et al combined interscalene brachial plexus block with general anaesthesia and found that the maximum decrease in systolic blood pressure from baseline was significantly greater in the patients with interscalene block in agreement with our results [46].

Pinnock showed on a strong relation between local anaesthetic regional technique and abolishment of the

Table 17. Comparison between the two studied groups according to time to first analgesic requirement (min).

	Time to first analgesic requirement(min)	
Case no.	ESP	Multimodal
1	0	60
2	0	120
3	120	120
4	60	240
5	120	120
6	120	60
7	480	60
8	480	120
9	0	120
10	0	240
11	120	120
12	120	60
13	480	60
14	480	60
15	0	120
Not received	5 (33.3%)	0 (0.0%)
Received	10 (66.7%)	15 (100.0%)
Min.	0.0	60.0
Max.	480.0	240.0
Mean	172.0	112.0
±SD.	198.83	59.43
U	114.50	
p	0.931	

U: Mann–Whitney test
p: *p* value for comparing between the two groups

Table 18a. Change in postoperative analgesia time intervals in ESP group.

	Postoperative analgesia time intervals			
Cases no.	1 h	2 h	4 h	8 h
1	0	0	0	0
2	0	0	0	0
3	0	25	0	0
4	25	0	0	0
5	0	25	0	0
6	0	25	0	0
7	0	0	0	25
8	0	0	0	25
9	0	0	0	0
10	0	0	0	0
11	0	25	0	0
12	0	25	0	0
13	0	0	0	25
14	0	0	0	25
15	0	0	0	0
Min.	0.0	0.0	0.0	0.0
Max.	25.0	25.0	0.0	25.0
Mean	1.67	8.33	0.0	6.67
±SD.	6.45	12.20	0.0	11.44
Median	0.0	0.0	0.0	0.0

Table 18b. Change in postoperative analgesia time intervals in multimodal group.

	Postoperative analgesia time intervals			
Cases no.	1 h	2 h	4 h	8 h
1	25	0	0	0
2	0	25	0	0
3	0	25	0	0
4	0	0	25	0
5	0	25	0	0
6	25	0	0	25
7	25	0	0	0
8	0	25	0	0
9	0	25	0	0
10	0	0	25	0
11	0	25	0	0
12	25	0	0	0
13	25	0	0	0
14	0	25	0	0
15	0	25	0	0
Min.	0.0	0.0	0.0	0.0
Max.	25.0	25.0	25.0	25.0
Mean	8.33	13.33	3.33	1.67
±SD.	12.20	12.91	8.80	6.45
Median	0.0	25.0	0.0	0.0

sympathoadrenal, metabolic and immunological stress response [47]. While Hamilton et al supposed some possibilities about how ESP could spread to the ventral rami of the spinal nerves, it may spread to the paravertebral or epidural space and sequentially result in probable hypotension [48].

Also, Bang et al outlined many newly experienced applications of the ESP and that the site of action of this injected local anaesthetics is at the dorsal and ventral rami of the thoracic or lumbar spinal nerves and, thus, it is expected to block the ventral rami and the sympathetic fibres leading to effective management of somatic and visceral pains [49].

For group I (ESP), the mean time to modified aldrete score > 9 was 22.13 ± 4.50 min. While for group II (multimodal), it was 20.0 ± 5.49 min. There was no statistically significant difference between the two groups (p value = 0.054).

Although group I patients had significant decreased anaesthesia emergence time probably due to decreased anaesthetic requirements and fentanyl consumption, time to modified aldrete score > 9 was not statistically significant. Delayed recovery from anaesthesia was multifactorial and anaesthetic agents may not be absolutely the offender. This included patient factors like genetic variation, body habitus and cognitive status or metabolic factors like hypothermia and hypothyroidism or surgical/anaesthetic factors like duration of surgery and combined regional anaesthesia with anaesthetic drugs which was of possible correlation with our results; presence of pain may enhance arousal whereas somnolence may be maintained with regional anaesthetic techniques [50].

Pethidine increments were given based on reaching VAS 4 and there was a statistically significant difference between the two groups at the second time interval

Table 18c. Comparison between the two studied groups according to postoperative analgesia time intervals.

	Postoperative analgesia time intervals			
	1 h	2 h	4 h	8 h
ESP				
Min.	0.0	0.0	0.0	0.0
Max.	25.0	25.0	0.0	25.0
Mean	1.67	8.33	0.0	6.67
±SD.	6.45	12.20	0.0	11.44
Median	0.0	0.0	0.0	0.0
Multimodal				
Min.	0.0	0.0	0.0	0.0
Max.	25.0	25.0	25.0	25.0
Mean	8.33	18.33	3.33	1.67
±SD.	12.20	11.44	8.80	6.45
Median	0.0	25.0	0.0	0.0
U	142.50	157.5*	127.50	90.0
p	0.073	0.031*	0.150	0.367

t: Student *t*-test
p: *p* value for comparing between the two groups

Table 19. Comparison between the two studied groups according to total pethidine (mg).

	Total pethidine (mg)		
Case no.	ESP		Multimodal
1	0		50
2	0		25
3	25		25
4	25		25
5	25		25
6	25		25
7	25		50
8	25		25
9	0		25
10	0		25
11	25		25
12	25		25
13	25		50
14	25		25
15	0		25
Not received	5 (33.3%)		0 (0.0%)
Received	10 (66.7%)		15 (100.0%)
Min.	0.0		25.0
Max.	25.0		50.0
Mean	16.67		30.0
±SD.	12.20		10.35
Median	25.0		25.0
U		165.0*	
p		0.029*	

U: Mann–Whitney test
p: *p* value for comparing between the two groups
*: Statistically significant at $p \leq 0.05$

Table 20. Comparison between the two studied groups according to surgical area bleeding score.

Surgical area bleeding score	ESP (n = 15)	Multimodal (n = 15)	χ^2	MC_p
Minimal	2 (13.3%)	0 (0.0%)		
Mild	8 (53.3%)	9 (60.0%)	1.825	0.547
Moderate	5 (33.3%)	6 (40.0%)		
Severe	0 (0.0%)	0 (0.0%)		

x^2: Chi-square testMC: Monte Carlo
p: *p* value for comparing between the two groups

(2 h) (*p* value 0.031), also regarding the total dose of pethidine given (*p* value 0.029)

We found decreased opioid requirements in group I ESP and the needed increments were at the end of the time frame evaluated which may justify the reasonable time period of the bupivacaine action.

Zhang et al performed ESP in patients underwent lumbar spine surgery and found postoperative morphine consumption (P = 0.003) were lower in the intervention group than in the control group [51].

Takahashi et al firstly tested the efficacy of ESP in failed back surgery syndrome in a case report. After performing the block, oral analgesic drugs; acetaminophen and tramadol were not received and pain relief was reported till 10 h postprocedure, complete relief was achieved after three injections over few months [52].

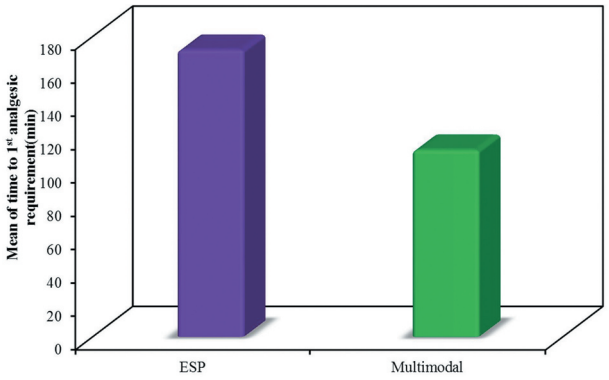

Figure 19. Comparison between the two studied groups according to time to first analgesic requirement (min).

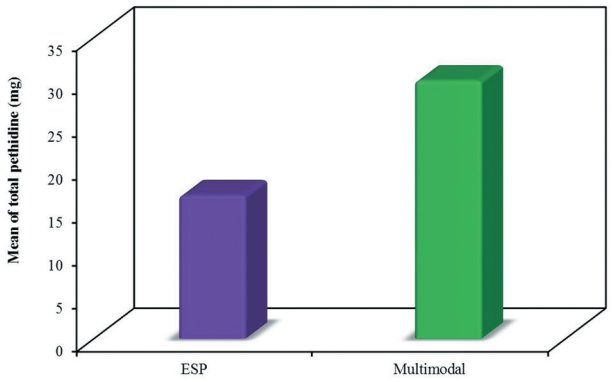

Figure 21. Comparison between the two studied groups according to total pethidine (mg).

For group I (ESP), the mean time to first analgesic requirements based on reaching the score of 4 VAS was 172.0 ± 198.83 min. Five patients (33.3%) did not need pethidine at any time intervals, while ten patients (66.7%) needed pethidine at variable time intervals.

For group II (MMA), the mean time to first analgesic requirements based on reaching the score of 4 VAS was 112.0 ± 59.43 min. All the fifteen patients (100%) received pethidine at variable time intervals.

There was no statistically significant difference between the two groups as regards the time to first analgesic requirements (min) based on reaching the score of 4 VAS (*p* value 0.931) although it might be clinically prolonged in group I more than that of group II.

Ahiskalioglo et al reported first analgesic requirements range 6–14 h and the median was 8 h after performing ESP for hip surgeries [53].

Goyal et al studied bilateral ESP in cervical spine fracture patient that underwent cervival spine fusion, only paracetamol 500 mg 6 hourly without any other opioid drugs were given up to 48 h postoperatively and NRS ranged 1–3 [43].

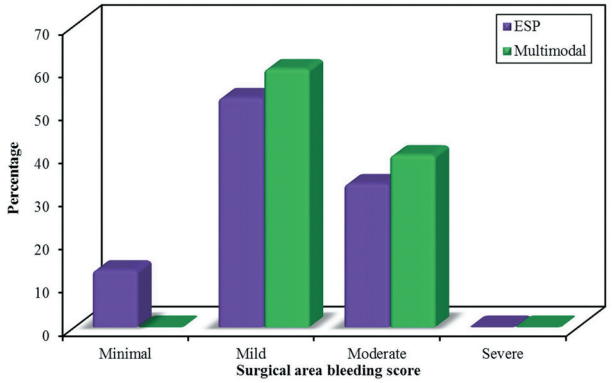

Figure 22. Comparison between the two studied groups according to surgical area bleeding score.

Cesur et al studied five cases that had lumbar spine surgery under general anaesthesia combined with erector spinae plane block in a case series study, they summarized that the NRS 4 was reached 8 h postsurgery and postoperative total 24 h tramadol consumption was 30–150 mg mostly 8 h postsurgery.[54]

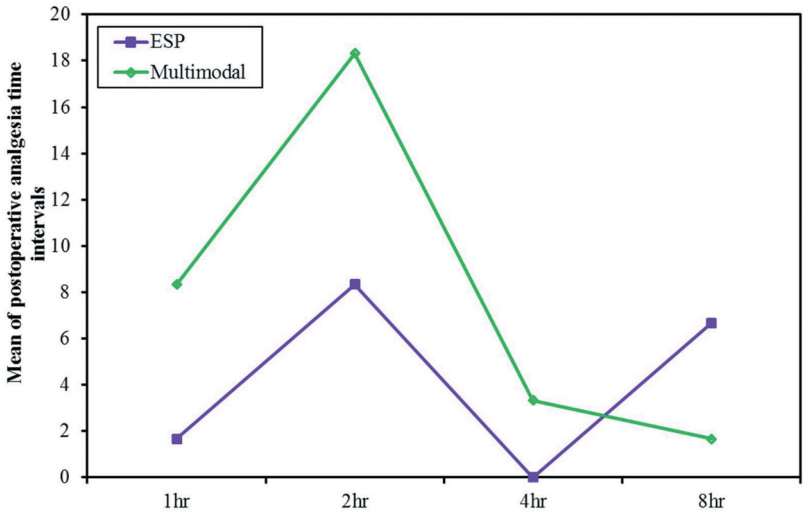

Figure 20. Comparison between the two studied groups according to postoperative analgesia time intervals.

5. Conclusions

Erector spinae plane block (ESP) can be considered safe and effective perioperative analgesic modality for lumbar spine simple decompression surgery. Lumbar spine interbody fusion surgery is more invasive and need more analgesic requirements. ESP may help in controlled hypotensive anaesthetic technique. It decreases inhalational anaesthetics and intraoperative opioid requirements, enhances recovery from anaesthesia and provides supportive analgesia up to 8 h postoperatively.

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Ethics statement

After the approval of The Local Ethics Committee and having an informed written consent from every patient, patients were randomly categorized into two equal groups (15 patients each) by closed envelope method:

Group I (ESP): Erector spinae plane block combined with general anaesthesia.

Group II (multimodal): Conventional general anaesthesia receiving multimodal analgesia. All patients were informed about the technique applied and any possible complications.

Disclosure statement

Ezzzt M. Siam, Doaa M. Abo Alia, Sally Elmedany ensure that all financial aspects for this work were supported by the corresponding author Mohamed E. Abdelaal and there were neither personal interests influencing the work nor financial relationships with any other entity or sponsor.

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