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Original Research Article

Comparative Evaluation of Opioid-Free and Opioid-Based Anaesthesia in Laparoscopic Surgery: A Prospective Randomized Study

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Abstract:

Background: Laparoscopic surgeries are widely performed under general anaesthesia, where haemodynamic stability is often challenged by stress responses to laryngoscopy, intubation, and pneumoperitoneum. Traditionally, opioids such as fentanyl are used to attenuate these responses; however, opioid-related side effects like respiratory depression, nausea, and delayed recovery have driven exploration of opioid-free anaesthesia (OFA) protocols using agents such as dexmedetomidine, lignocaine, and bupivacaine.

Aim: To compare the haemodynamic stability and postoperative analgesia between opioid-based anaesthesia (fentanyl) and opioid-free anaesthesia (dexmedetomidine + lignocaine + bupivacaine) in patients undergoing laparoscopic surgeries.

Methods: This randomized, prospective study was conducted 80 ASA I–II adult patients aged 18–60 years were enrolled and divided into two groups (n=40 each).

- Group A (OGA): Fentanyl 2 µg/kg IV + maintenance boluses.
- Group B (OFA): Dexmedetomidine 0.7 µg/kg IV + lignocaine 1 mg/kg IV, followed by continuous dexmedetomidine (0.3 µg/kg/hr) and lignocaine (1.5 mg/kg/hr) infusions; local bupivacaine infiltration at closure.

Haemodynamic parameters (HR, SBP, DBP, MAP, SpO_2, $EtCO_2$) were recorded at baseline, induction, post-intubation, and throughout surgery. Postoperative pain was assessed using the Visual Analogue Scale (VAS). Data were analysed using Student's t-test; $p<0.05$ was considered significant.

Results: Both groups were demographically comparable. The OFA group exhibited significantly attenuated rises in HR and MAP post-intubation ($p<0.001$). Postoperative pain scores were lower in OFA at 2, 4, and 6 hours (VAS <3), with reduced need for rescue analgesia. Incidence of nausea and vomiting was lower in OFA (5%) than OGA (22%). No severe bradycardia or hypotension was observed.

Conclusion: Opioid-free anaesthesia using dexmedetomidine and lignocaine with local bupivacaine provides superior haemodynamic stability and prolonged postoperative analgesia compared to fentanyl-based anaesthesia, with fewer opioid-related adverse effects. OFA is a safe and effective alternative for laparoscopic procedures.

Keywords: Opioid-Free Anaesthesia, Fentanyl, Dexmedetomidine, Lignocaine, Bupivacaine, Hemodynamics, Laparoscopic Surgery, Analgesia.

Introduction

Laparoscopic surgery is a minimally invasive approach frequently used for abdominal and pelvic procedures such as appendectomy, cholecystectomy, and hernia repair [1]. These surgeries require pneumoperitoneum with carbon dioxide, which can alter cardiopulmonary physiology by increasing intra-abdominal pressure, reducing venous return, and stimulating the sympathetic nervous system [2]. Such physiological changes, compounded by laryngoscopy and intubation, lead to tachycardia, hypertension, and increased myocardial oxygen demand [3]. Traditionally, opioids such as fentanyl have been the mainstay for attenuating stress responses [4]. While effective, opioids cause dose-dependent respiratory depression, nausea, vomiting, constipation, pruritus, delayed recovery, and in some cases, opioid-induced hyperalgesia [5]. These limitations have prompted anaesthesiologists to explore opioid-sparing or opioid-free anaesthesia (OFA). Dexmedetomidine, a selective α_2-adrenergic agonist, offers sedation, anxiolysis, and sympatholysis without respiratory depression [6]. Intravenous lignocaine reduces sympathetic activation and provides analgesia [7], while bupivacaine infiltration at the surgical site reduces local nociceptive input. Together, they create a multimodal, non-opioid strategy for maintaining haemodynamic stability and improving

postoperative recovery [8]. This study compares the efficacy of OFA (dexmedetomidine + lignocaine + bupivacaine) versus traditional opioid-based anaesthesia (fentanyl) in terms of intraoperative hemodynamics and postoperative analgesia in laparoscopic surgery.

Materials and Methods

Study Design and Setting: A hospital-based, randomized, prospective comparative study was conducted in the Department of Anaesthesiology.

Inclusion Criteria:

- Age 18–60 years
- ASA Physical Status I–II
- BMI < 30 kg/m²
- Elective laparoscopic surgeries

Exclusion Criteria:

- Pregnancy/lactation
- Systemic disease or haemodynamic instability
- Anticipated difficult airway
- Known allergy to study drugs
- Emergency surgeries

Sample Size: Based on prior studies and Open Epi calculation (power 80%, $\alpha = 0.05$), a minimum of 72 patients was required. To strengthen validity, 80 patients were enrolled (40 per group).

Grouping and Intervention:

Group A (OGA):

- Fentanyl 2 µg/kg IV before induction
- Maintenance bolus 0.5 µg/kg as required
- Group B (OFA):
- Dexmedetomidine 0.7 µg/kg IV (over 10 min)
- Lignocaine 1 mg/kg IV before induction
- Continuous infusion: Dexmedetomidine 0.3 µg/kg/hr + Lignocaine 1.5 mg/kg/hr
- 0.25% Bupivacaine infiltration at port sites at closure

Anaesthesia Protocol: All patients were premedicated with:

- Ondansetron 4 mg IV
- Glycopyrrolate 0.2 mg IV
- Pantoprazole 40 mg IV
- Midazolam 0.02 mg/kg IV

Induction: Propofol 2 mg/kg + Succinylcholine 1.5 mg/kg. Maintenance: Desflurane (O_2: N_2O = 1:2), Atracurium 0.5 mg/kg, IPPV mode with $EtCO_2$ maintained at 35–45 mmHg. At completion: Neostigmine 0.05 mg/kg + Glycopyrrolate 0.01 mg/kg for reversal.

Outcome Measures:

- Primary: HR, MAP intraoperatively
- Secondary: Postoperative VAS pain scores, side effects

Statistical Analysis: Data were analysed using Microsoft Excel and Epi Info. Values expressed as Mean ± SD. Tests used: Student's t-test and Chi-square. $p < 0.05$ significant; $p < 0.001$ highly significant.

Results

Table 1: Demographic characteristics

Parameter	Group A (OGA)	Group B (OFA)	P-Value
Age (years, Mean ± SD)	32.83 ± 8.61	29.83 ± 5.52	0.067
Weight (kg, Mean ± SD)	54.28 ± 7.34	53.78 ± 7.87	0.770
Sex (M/F)	18/22	17/23	0.82

Both groups were comparable in terms of demographic characteristics, with no statistically significant differences in age, weight, or gender distribution ($p > 0.05$). This indicates that the baseline profiles of patients in the opioid-based (Group A) and opioid-free (Group B) anaesthesia groups were similar, ensuring that outcome differences observed in the study were not influenced by demographic variations.

Table 2: Trend of Heart Rate post-intubation

Time Point	Group A (OGA)	Group B (OFA)	P-Value
Baseline	84 ± 6.2 bpm	82 ± 5.8 bpm	0.42
1-minute post-intubation	106 ± 8.4 bpm	90 ± 7.2 bpm	<0.001
5 minutes post-intubation	102 ± 7.9 bpm	88 ± 6.8 bpm	<0.001
10 minutes	96 ± 7.3 bpm	85 ± 6.4 bpm	<0.001
30 minutes	90 ± 6.5 bpm	82 ± 5.9 bpm	0.002

Heart rate remained comparable at baseline between both groups. Following intubation, Group A (OGA) showed a significant rise in heart rate at all time points, whereas Group B (OFA) maintained near-baseline levels, demonstrating better hemodynamic stability due to the sympatholytic effect of dexmedetomidine ($p < 0.001$).

Table 3: Mean Arterial Pressure comparison

Time Point	Group A (Mmhg)	Group B (Mmhg)	P-Value
Baseline	92.4 ± 7.5	91.8 ± 6.9	0.71
1 min post-intubation	108.6 ± 9.1	95.3 ± 8.7	<0.001
5 min	104.8 ± 8.6	92.9 ± 7.5	<0.001
10 min	100.2 ± 7.9	90.7 ± 6.8	0.002
30 min	94.6 ± 6.3	89.2 ± 6.7	0.03

Mean arterial pressure (MAP) was comparable at baseline between both groups.

However, following intubation, Group A (OGA) exhibited a significant rise in MAP at all subsequent time points, while Group B (OFA) maintained relatively stable values closer to baseline. This indicates that dexmedetomidine in the OFA group provided better hemodynamic control and attenuation of pressor response during the peri-intubation period ($p < 0.05$).

Table 4: Postoperative VAS Scores

Time	Group A	Group B	P-Value
0 hr	3.65 ± 0.72	2.84 ± 0.61	0.001
2 hr	4.32 ± 0.80	2.50 ± 0.69	<0.001
6 hr	4.85 ± 0.92	2.76 ± 0.73	<0.001
12 hr	3.90 ± 0.80	2.45 ± 0.70	<0.001
24 hr	2.65 ± 0.58	1.92 ± 0.50	0.004

Pain scores were significantly higher in Group A (OGA) compared to Group B (OFA) at all postoperative time intervals ($p < 0.05$). Group B consistently demonstrated lower pain scores, indicating superior and sustained analgesia with the opioid-free anesthesia regimen throughout the 24-hour postoperative period.

Table 5: Adverse effects comparison

Complication	OGA (%)	OFA (%)
Nausea/Vomiting	22	5
Bradycardia	5	10
Hypotension	5	8
Respiratory Depression	8	0

Postoperative complications differed notably between the groups. Nausea and vomiting were more frequent in the OGA group (22%) compared to the OFA group (5%), highlighting the opioid-related side effect profile.

Bradycardia (10%) and hypotension (8%) were slightly more common in the OFA group, likely due to dexmedetomidine's sympatholytic action, though these were clinically manageable. Respiratory depression occurred only in the OGA group (8%), underscoring the respiratory safety advantage of the opioid-free anesthesia regimen.

Discussion

This study demonstrates that opioid-free anaesthesia (OFA) using dexmedetomidine and lignocaine with local bupivacaine provides superior haemodynamic stability and analgesic quality compared to opioid-based anaesthesia (OGA) with fentanyl during laparoscopic surgery.

The attenuated rise in HR and MAP in the OFA group can be attributed to dexmedetomidine's central α_2 agonism, suppressing sympathetic outflow and stress-induced catecholamine release [6]. Lignocaine's sodium channel blockade and anti-inflammatory effects further stabilize hemodynamics [7].

These findings align with prior reports:

- Bajwa et al. (2012) and Kharwar et al. (2014) found dexmedetomidine more effective than fentanyl in blunting pressor responses [9,10].
- Patel et al. (2015) observed significantly lower BP and HR with dexmedetomidine than with fentanyl [11].
- Frauenknecht et al. (2019) showed reduced postoperative nausea/vomiting and comparable analgesia in OFA protocols [12].
- Hariharan et al. (2023) and Chen et al. (2023) confirmed OFA's role in reducing opioid-related side effects and providing effective analgesia [13,14].

The lower postoperative VAS scores in the OFA group emphasize lignocaine's and dexmedetomidine's synergistic analgesic action [6,7].

The addition of local bupivacaine further reduced nociceptive transmission from incision sites, extending pain-free duration and reducing analgesic demand [8]. Adverse events were minor. Bradycardia was slightly more frequent in OFA but

easily managed with atropine. Importantly, no cases of respiratory depression occurred in OFA, underscoring its safety profile—an advantage in outpatient and geriatric anaesthesia.

This multimodal OFA approach minimizes the physiological burden of opioids while maintaining anaesthetic depth and cardiovascular stability.

Furthermore, by reducing PONV and sedation, OFA may enhance early recovery and discharge readiness, aligning with Enhanced Recovery After Surgery (ERAS) principles [12,13,14].

Conclusion

Opioid-free anaesthesia utilizing dexmedetomidine, lignocaine, and bupivacaine is a safe, effective, and superior alternative to conventional fentanyl-based protocols in laparoscopic surgeries.

It ensures better haemodynamic control, prolonged postoperative analgesia, and lower incidence of opioid-related adverse effects without compromising intraoperative stability.

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