RESEARCH PAPER

Comparison of Recovery Profiles in Target Controlled Infusion Versus Manual Controlled Infusion in Total Intravenous Anaesthesia Using Propofol and Remifentanil in Laparoscopic Surgeries: A Prospective Randomised Controlled Study

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ABSTRACT

Background: Total intravenous anaesthesia (TIVA) using propofol and remifentanil is widely employed for laparoscopic surgeries owing to its favourable pharmacokinetic profile, haemodynamic stability, and superior recovery characteristics. Two principal methods of drug delivery are used: Manual Controlled Infusion (MCI), in which infusion rates are adjusted empirically by the anaesthesiologist, and Target Controlled Infusion (TCI), in which a pharmacokinetic model-driven pump maintains a predetermined effect-site drug concentration. While TCI offers theoretical advantages in titration precision, head-to-head comparative evidence for recovery outcomes in elective laparoscopic TIVA remains limited.

Objective: To compare recovery profiles, depth of anaesthesia, haemodynamic stability, anaesthetic drug consumption, and postoperative analgesic requirements between MCI and TCI techniques of TIVA using propofol and remifentanil in adult patients undergoing elective laparoscopic surgery.

Methods: This prospective, randomised, single-blind controlled study was conducted at a tertiary care institution following Institutional Ethics Committee approval (Ref: ASCOMS/IEC/2024/Meeting-II/14). Seventy ASA Grade I–II adults aged 18–65 years scheduled for elective laparoscopic surgery were randomised into two equal groups (n=35 each): Group MCI received propofol via a conventional manual syringe infusion pump, and Group TCI received propofol via the Benefusion TCI pump (Mindray) using the Schnider pharmacokinetic model based on patient BMI. Remifentanil was administered by conventional infusion pump in both groups. Anaesthetic depth was objectively monitored using the CONOX system (Fresenius Kabi), targeting qCON and qNOX values between 40 and 60. The primary outcomes were four sequential recovery milestones measured from cessation of propofol infusion: T1 (return of spontaneous ventilation), T2 (response to verbal commands), T3 (time to extubation), and T4 (time to achieve Modified Aldrete Score ≥9 for transfer). Secondary outcomes included haemodynamic parameters, qCON and qNOX indices, total drug consumption, and postoperative rescue analgesia requirement. Statistical analysis was performed using SPSS version 25.0; a p-value <0.05 was considered statistically significant.

Results: Both groups were comparable at baseline with respect to age (p=0.658), sex (p=0.131), ASA grade (p=0.631), type of surgery (p=0.597), and anthropometric parameters (p>0.05 for all). T1 did not differ significantly between MCI and TCI (10.94±2.21 vs 10.71±2.04 min; p=0.534). However, statistically significant advantages were observed with TCI at T2 (14.49±2.66 vs 14.14±2.00 min; p=0.042), T3 (18.60±2.53 vs 18.14±1.82 min; p=0.047), and T4 (23.34±2.83 vs 22.66±2.62 min; p=0.008). Total propofol consumption was significantly lower in TCI (766.74±87.94 vs 891.43±197.15 mg; p<0.001), though surgery duration was also shorter in TCI (57.94±20.41 vs 69.57±22.98 min; p=0.009). qCON after stopping propofol (82.63±2.79 vs 81.57±4.13; p=0.022) and at extubation (91.40±2.39 vs 90.69±3.03; p=0.024) were significantly higher in TCI, indicating earlier cortical recovery. Modified Aldrete Score at shifting was higher in MCI (9.89±0.52 vs 9.01±0.63; p=0.038), though both groups met the minimum threshold. Haemodynamic parameters remained stable throughout. Rescue analgesia requirement was comparable (MCI 40.0% vs TCI 45.7%; p=0.629).

Conclusion: In ASA I–II adults undergoing elective laparoscopic surgery with propofol–remifentanil TIVA, TCI was associated with modestly but significantly faster attainment of later recovery milestones (T2–T4), earlier cortical recovery on qCON monitoring, and lower total propofol consumption compared to MCI. Both techniques provided equivalent haemodynamic stability and postoperative analgesic requirements. TCI may be regarded as a precision refinement of TIVA delivery rather than a replacement for MCI, and technique selection should be guided by institutional resources, clinical context, and operator familiarity.

Keywords: Total intravenous anaesthesia (TIVA); Target controlled infusion (TCI); Manual controlled infusion (MCI); Propofol; Remifentanil; Laparoscopic surgery; Recovery profiles; Modified Aldrete Score

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INTRODUCTION

Laparoscopic surgery has become an integral component of modern surgical practice owing to its advantages of smaller incisions, reduced postoperative pain, shorter hospital stay, and faster recovery when compared with conventional open procedures. However, physiological alterations induced by pneumoperitoneum and patient positioning present unique anaesthetic challenges, necessitating precise control of anaesthetic depth, maintenance of haemodynamic stability, and rapid postoperative recovery (**1**).

Total intravenous anaesthesia (TIVA) has emerged as an attractive alternative to inhalational anaesthesia because it provides smooth induction, stable intraoperative conditions, rapid emergence, and a lower incidence of postoperative nausea and vomiting. The combination of propofol and remifentanil has become particularly popular owing to the favourable pharmacokinetic properties of both agents. Propofol offers rapid onset and recovery, while remifentanil provides potent analgesia with an ultra-short duration of action, allowing precise titration of anaesthesia throughout surgery (**2-4**).

Two principal techniques are currently employed for administering TIVA: manual controlled infusion (MCI) and target controlled infusion (TCI). In MCI, drug delivery is adjusted manually according to clinical signs and anaesthesiologist judgement. In contrast, TCI utilizes computer-driven infusion pumps based on pharmacokinetic models to achieve and maintain predetermined plasma or effect-site drug concentrations. By incorporating patient-specific variables and continuously adjusting infusion rates, TCI aims to provide more precise control of anaesthetic depth and improved drug titration throughout the perioperative period (**5-7**).

Recovery from anaesthesia is a critical determinant of perioperative outcome, particularly in laparoscopic procedures where early mobilization and discharge are desirable. The short context-sensitive half-lives of propofol and remifentanil facilitate rapid recovery; however, the method of drug administration may significantly influence recovery characteristics. TCI systems are believed to provide smoother emergence, more predictable wake-up times, reduced fluctuations in drug concentrations, and improved haemodynamic stability compared with conventional manual infusion techniques (**8-11)**

Several investigators have compared TCI and MCI techniques with respect to anaesthetic consumption, depth of anaesthesia, haemodynamic stability, and recovery profile. While studies (**12-17).** have demonstrated potential advantages of TCI in maintaining consistent anaesthetic depth and facilitating recovery, the evidence remains inconclusive, particularly in patients undergoing laparoscopic surgery. Therefore, the present study was undertaken to compare the recovery profiles of target controlled infusion and manual controlled infusion during total intravenous anaesthesia using propofol and remifentanil in patients undergoing elective laparoscopic surgeries.

MATERIALS AND METHODS

Study Design and Setting

This prospective randomized comparative study was conducted in the Department of Anaesthesiology and Intensive Care, Acharya Shri Chander College of Medical Sciences and Hospital, Sidhra, Jammu, from June 2024 to November 2025, after obtaining approval from the Institutional Ethics Committee and written informed consent from all participants.

Study Population

A total of 70 patients of either sex, aged 18–65 years, belonging to the American Society of Anesthesiologists (ASA) physical status I and II, scheduled for elective laparoscopic surgeries under general anaesthesia were enrolled in the study.

Exclusion Criteria

Patients who refused consent, ASA physical status III–IV, age below 18 years or above 65 years, pregnant patients, full stomach patients, patients with significant cardiovascular, respiratory, hepatic or renal disease, and surgeries lasting more than 4 hours were excluded.

Randomization and Group Allocation

Patients were randomly allocated into two equal groups (n=35 each) using a computer-generated randomization sequence placed in sealed opaque envelopes.

- **Group TCI (n=35):** Received total intravenous anaesthesia (TIVA) using target-controlled infusion of propofol with remifentanil.
- **Group MCI (n=35):** Received TIVA using manually controlled infusion of propofol with remifentanil.

The observer recording postoperative recovery parameters was blinded to group allocation.

Anaesthetic Technique

All patients underwent standard pre-anaesthetic evaluation. After arrival in the operating room, routine monitoring including electrocardiography, non-invasive blood pressure, pulse oximetry, end-tidal carbon dioxide and CONOX monitoring (qCON and qNOX) was instituted.

Patients received intravenous ondansetron (0.1 mg/kg) and midazolam (1–2 mg) as premedication. Following preoxygenation with 100% oxygen for 3 minutes, remifentanil infusion was initiated at 0.1 µg/kg/min.

In the **TCI group**, propofol infusion was administered using a Mindray Benefusion target-controlled infusion pump employing the Schnider pharmacokinetic model. Propofol effect-site concentration was titrated to maintain qCON values between 40 and 60.

In the **MCI group**, propofol was administered through a conventional syringe infusion pump and titrated according to clinical response and qCON values maintained between 40 and 60.

Neuromuscular blockade was achieved with rocuronium 0.6 mg/kg to facilitate endotracheal intubation. Mechanical ventilation was adjusted to maintain normocapnia. Additional adjustments in remifentanil infusion were guided by qNOX values and surgical stimulation.

At the completion of surgery, intravenous paracetamol 1 g was administered for postoperative analgesia. Propofol infusion was discontinued after completion of skin closure. Neuromuscular blockade was reversed with neostigmine (0.05 mg/kg) and glycopyrrolate (0.01 mg/kg) according to train-of-four monitoring.

Outcome Measures

Primary Outcomes

Recovery profile was assessed using the following parameters:

1. Time to return of spontaneous ventilation.
2. Time to response to verbal commands.
3. Time to extubation.
4. Time to achieve adequate recovery for transfer from the operating room, assessed using the Modified Aldrete Recovery Score (MARS).

Secondary Outcomes

Secondary outcome measures included:

- Intraoperative heart rate and blood pressure.
- qCON and qNOX values.
- Total propofol and remifentanil consumption.
- Duration of surgery and anaesthesia.
- Postoperative pain, nausea and vomiting.
- Adverse perioperative events.

Statistical Analysis

Data were analysed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation and compared using the Student's t-test. Categorical variables were analysed using the Chi-square test or Fisher's exact test as appropriate. A p-value <0.05 was considered statistically significant.

RESULTS

This prospective randomised comparative study enrolled 70 adult patients undergoing elective laparoscopic surgery who were allocated equally to two groups: Manual Controlled Infusion (MCI, n=35) and Target Controlled Infusion (TCI, n=35). All patients completed the study with no dropouts. The results are presented under the following headings: patient demographics and baseline characteristics; depth-of-anaesthesia indices (qCON and qNOX); haemodynamic parameters; recovery time milestones (T1–T4); anaesthetic drug consumption and surgery duration; Modified Aldrete Score at shifting; and rescue analgesia requirement.

1. Patient Demographics and Baseline Characteristics

The two groups were well matched at baseline with regard to age distribution, sex ratio, ASA physical status grade, type of laparoscopic procedure and anthropometric variables (Table 1). No statistically significant inter-group difference was observed for any demographic parameter, confirming that the groups were comparable at the outset of the study.

Table 1: Demographic profile and baseline anthropometric characteristics of patients in MCI and TCI groups

Variable	Category	MCI (n=35)	TCI (n=35)	Total (n=70)	p-value
Age (years)					**0.658**
	≤ 20	1	1	2	
	21–30	4	7	11	
	31–40	11	7	18	
	41–50	5	6	11	
	51–60	11	8	19	
	61–70	3	6	9	
Sex					**0.131**
	Female	12	21	33	
	Male	23	14	37	
ASA Grade					**0.631**
	Grade I	18	20	38	
	Grade II	17	15	32	
Type of Surgery					**0.597**
	Lap. Cholecystectomy	26	24	50	

	Lap. Hernia Repair	9	11	20	
Anthropometric Parameters					
Weight (kg)		65.49 ± 9.44	64.06 ± 9.42	—	0.717
Height (cm)		164.17 ± 4.27	164.14 ± 4.63	—	0.863
BMI (kg/m²)		23.84 ± 3.29	23.75 ± 3.01	—	0.577

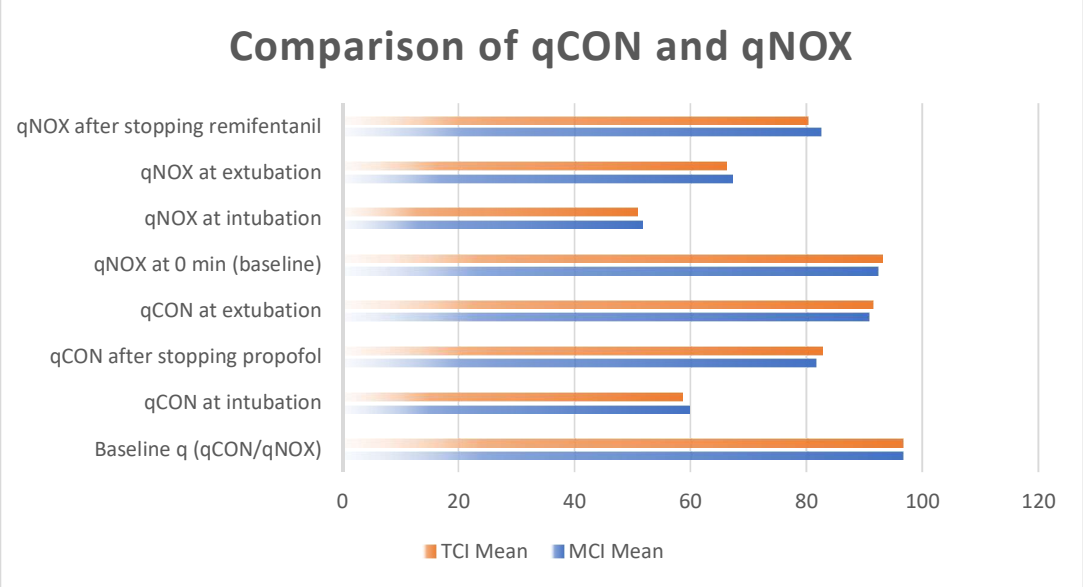
Values for anthropometric parameters expressed as Mean ± SD. NS = Not Significant. p < 0.05 considered statistically significant.

The age distribution was similar in both groups (p = 0.658), with the majority of patients clustered between 31–60 years. Sex distribution showed 33 females (47.1%) and 37 males (52.9%) overall; the difference between groups was not significant (p = 0.131). Regarding ASA physical status, 38 patients (54.3%) were Grade I and 32 (45.7%) were Grade II, with comparable distribution across groups (p = 0.631). Among the surgical procedures, laparoscopic cholecystectomy constituted 50 cases (71.4%) and laparoscopic hernia repair 20 cases (28.6%), with no significant inter-group difference (p = 0.597). Anthropometric parameters — weight, height and BMI — were statistically comparable between the two groups (p = 0.717, 0.863 and 0.577, respectively).

2. Depth of Anaesthesia: qCON and qNOX Values

Anaesthetic depth was objectively monitored using the CONOX system (Fresenius Kabi), which generates a Quantitative Consciousness Index (qCON) derived from EEG and a Quantitative Nociceptive Index (qNOX) derived from EMG. Both indices were recorded at four key time points: baseline (0 min), at intubation, at extubation, and after cessation of propofol/remifentanil infusion (Table 2).

Figure 1 : Comparison of qCON and qNOX values between MCI and TCI groups at key time points

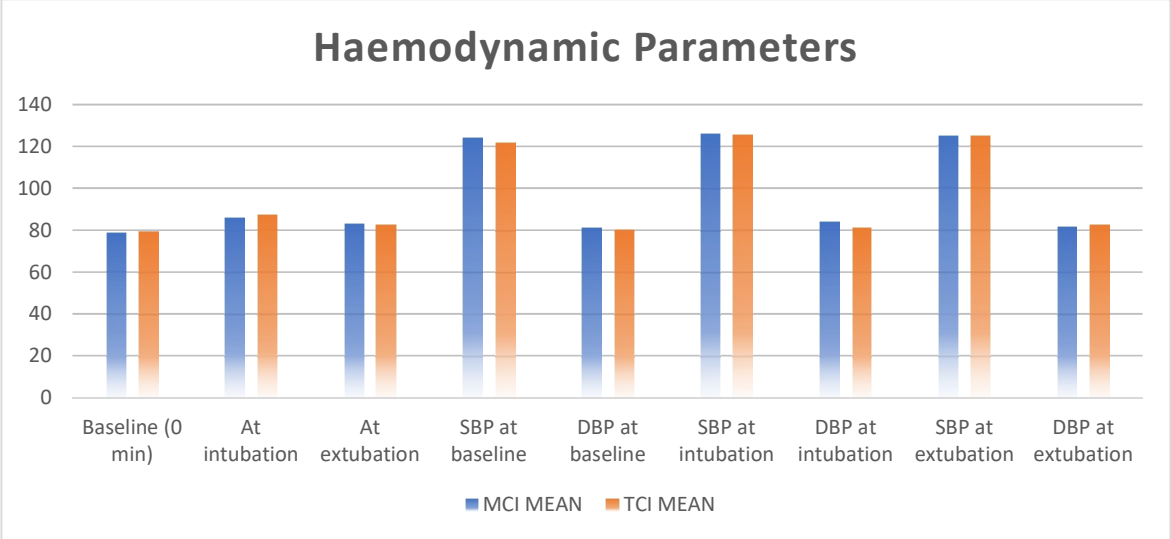


*Values expressed as Mean ± SD. NS = Not Significant; * p < 0.05; ** p < 0.01.*

Baseline q values were virtually identical in both groups (p = 0.887), confirming comparable pre-anaesthetic states. The qCON at intubation was also similar (p = 0.237), indicating equivalent hypnotic depth at laryngoscopy. However, qCON after cessation of propofol (p = 0.022) and at extubation (p = 0.024) were significantly higher in the TCI group, indicating a lighter cortical state and earlier return of consciousness during late emergence. All qNOX values showed statistically significant differences between groups at every recorded time point (p = 0.002 to 0.040), reflecting subtle but consistent differences in nociceptive processing between the two infusion strategies, despite both groups maintaining indices within the target range of 40–60 intraoperatively.

3. Haemodynamic Parameters

FIGURE 2; Haemodynamic Parameters



*SBP = Systolic Blood Pressure; DBP = Diastolic Blood Pressure. * p < 0.05; ** p < 0.01; NS = Not Significant.*

Heart rate showed statistically significant differences at all three time points, though absolute magnitudes were small and both groups remained within acceptable haemodynamic limits. Baseline SBP was comparable (p = 0.767); however, DBP at baseline (p = 0.045), SBP and DBP at intubation (p = 0.027 and 0.047), and both pressures at extubation (p = 0.046 and 0.003) demonstrated statistically significant differences. No episode of haemodynamic instability requiring clinical intervention was recorded in either group.

4. Recovery Time Milestones (T1–T4)

Table 3: Comparison of recovery time intervals (T1–T4) between MCI and TCI groups

Recovery Milestone	MCI Mean ± SD (min)	TCI Mean ± SD (min)	p-value	Sig.
T1 – Return of spontaneous ventilation	10.94 ± 2.21	10.71 ± 2.04	0.534	NS
T2 – Response to verbal commands	14.49 ± 2.66	14.14 ± 2.00	0.042	*
T3 – Time to extubation	18.60 ± 2.53	18.14 ± 1.82	0.047	*
T4 – Time to shift out of OR (Aldrete ≥9)	23.34 ± 2.83	22.66 ± 2.62	0.008	**

*Values in minutes from cessation of propofol (T0). NS = Not Significant; * p < 0.05; ** p < 0.01.*

T1 was equivalent between groups (p = 0.534), indicating similar initial respiratory recovery. Progressive and statistically significant differences favouring TCI emerged at T2 (p = 0.042), T3 (p = 0.047), and T4 (p = 0.008). This stepwise pattern — with the TCI group reaching later recovery milestones faster — is consistent with more controlled and predictable decline in effect-site drug concentrations afforded by pharmacokinetic model-guided infusion.

5. Anaesthetic Drug Consumption and Surgery Duration

Table 4: Comparison of total propofol and remifentanil consumption and surgery duration

Parameter	MCI Mean ± SD	TCI Mean ± SD	p-value	Sig.
Total propofol consumed (mg)	891.43 ± 197.15	766.74 ± 87.94	0.000	***
Propofol dose (mg/kg/hr)	13.72 ± 2.81	15.92 ± 22.42	0.015	*
Total remifentanil consumed (mcg)	65.49 ± 9.44	64.06 ± 9.42	0.017	*
Total surgery duration (min)	69.57 ± 22.98	57.94 ± 20.41	0.009	**

**** p < 0.001; ** p < 0.01; * p < 0.05.*

Total propofol in absolute milligrams was significantly higher in MCI (p = 0.000), while propofol per kg/hr was higher in TCI (p = 0.015) with a wide SD reflecting case duration variability. Remifentanil consumption differed modestly (p = 0.017). Surgery was significantly shorter in the TCI group (p = 0.009), an important contextual variable for interpreting drug totals.

6. Modified Aldrete Score at Shifting

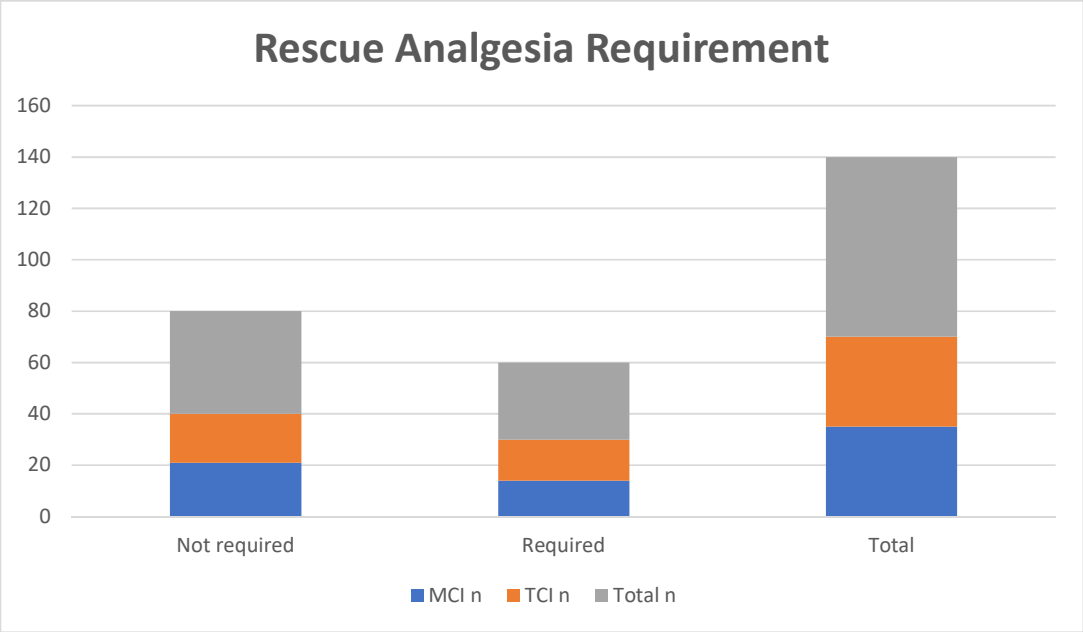
Table 5: Modified Aldrete Score at shifting between MCI and TCI groups

Parameter	MCI Mean ± SD	TCI Mean ± SD	p-value	Sig.
Modified Aldrete Score at shifting	9.89 ± 0.52	9.01 ± 0.63	0.038	*

The MCI group had a significantly higher composite Aldrete score at transfer (p = 0.038). Both groups met the minimum threshold of ≥9 for safe PACU transfer. This finding contrasts with the shorter T2–T4 intervals in the TCI group, highlighting the complementary value of time-based and composite scoring in recovery assessment.

7. Rescue Analgesia Requirement

Figure 3: Rescue analgesia requirement between MCI and TCI groups



Rescue analgesia rates were similar between groups (40.0% MCI vs 45.7% TCI; p = 0.629), indicating that the mode of propofol infusion had no meaningful impact on early postoperative pain when a standardised propofol–remifentanil regimen was used.

Summary of Results

Both MCI and TCI achieved adequate intraoperative anaesthetic depth and haemodynamic stability. T1 was equivalent across groups; T2, T3 and T4 were modestly but significantly shorter with TCI. Total propofol in milligrams was lower in TCI, though surgery duration was also shorter in that group. Modified Aldrete Scores at shifting favoured MCI. Rescue analgesia requirements were similar between techniques.

DISCUSSION

The present study compared manual controlled infusion (MCI) and target controlled infusion (TCI) techniques of total intravenous anaesthesia using propofol and remifentanil in patients undergoing elective laparoscopic surgeries. The primary findings of the study were that both techniques provided adequate depth of anaesthesia, stable haemodynamic conditions, and satisfactory postoperative recovery. However, TCI was associated with lower total propofol consumption and slightly faster progression through the later stages of recovery.

The demographic characteristics and ASA physical status distribution were comparable between the two groups, ensuring homogeneity of the study population and minimizing the influence of confounding factors on the observed outcomes. Similar baseline characteristics have been reported in previous studies comparing TCI and manual infusion techniques, including those by **Kateliya et al.[16]** and **Chen et al[12].**, who evaluated TIVA in ASA I–II patients undergoing elective surgical procedures.

Assessment of depth of anaesthesia using qCON and qNOX monitoring demonstrated that both infusion techniques maintained adequate hypnosis and antinociception throughout surgery. Baseline qCON values and measurements at intubation were comparable between groups, indicating similar induction conditions. However, qCON values after discontinuation of propofol and at extubation were slightly higher in the TCI group, suggesting a more rapid emergence from anaesthesia. These findings are consistent with those reported by **Chen et al.[12]**, who observed comparable BIS values between TCI and manually controlled propofol administration. Similarly, **Kateliya et al.[16]** reported deeper intraoperative anaesthesia with TCI while maintaining comparable recovery characteristics.

Recovery profile remains one of the most important determinants of successful ambulatory and laparoscopic anaesthesia. In the present study, the time to return of spontaneous ventilation (T1) was similar in both groups. However, response to verbal commands (T2), extubation time (T3), and readiness for transfer from the operating room (T4) were significantly shorter in the TCI group. These findings suggest that TCI allows more predictable reduction of effect-site propofol concentrations during emergence, facilitating faster recovery. Similar observations were reported by **Sahu et al[17].**, who demonstrated significantly shorter recovery times with TCI compared with manual infusion. In contrast, **Kateliya et al[16].** found comparable recovery times between the two techniques despite deeper anaesthesia in the TCI group.

An important finding of the present study was the significantly lower total propofol requirement in the TCI group. Although both techniques achieved adequate anaesthetic depth, TCI delivered anaesthesia more efficiently, resulting in reduced overall drug consumption. This observation supports the theoretical advantage of pharmacokinetic model-based drug delivery, which continuously adjusts infusion rates according to predicted plasma and effect-site concentrations. Similar findings have been reported by **Kateliya et al[16].**, who observed efficient propofol utilization with TCI-guided anaesthesia. The lower propofol consumption observed in our study may be attributed to the use of the Schneider pharmacokinetic model, which incorporates patient-specific variables including body mass index and age.

Haemodynamic parameters remained clinically stable throughout the perioperative period in both groups. Although some statistically significant differences were observed at isolated time points, these differences were small and unlikely to be clinically relevant. The findings suggest that both MCI and TCI are capable of maintaining satisfactory cardiovascular stability during laparoscopic surgery. Comparable haemodynamic profiles have been described by **Chen et al.[12]** and **Breslin et al[18].**, who reported no major differences in cardiovascular responses between target-controlled and manually controlled propofol administration.

Interestingly, despite faster recovery times in the TCI group, the Modified Aldrete Score at shifting was marginally higher in the MCI group. This finding suggests that recovery quality cannot be assessed solely by time-based parameters and highlights the importance of evaluating functional recovery indices. Nevertheless, the difference was small and of uncertain clinical significance.

Postoperative analgesic requirements were similar in both groups, with no significant difference in the need for rescue analgesia. This finding indicates that the mode of propofol administration has minimal influence on early postoperative pain when remifentanil-based analgesia is used. Similar observations have been reported by **Ozkose et al[19].**, who demonstrated that postoperative analgesic requirements were primarily influenced by opioid-related factors rather than the hypnotic delivery technique.

Overall, the findings of the present study suggest that both MCI and TCI are safe and effective techniques for administering propofol-remifentanil TIVA in laparoscopic surgeries. While TCI offers advantages in terms of reduced propofol consumption and slightly faster recovery, MCI provides comparable depth of anaesthesia, haemodynamic stability, and postoperative analgesic outcomes. These results support the continued use of MCI in resource-limited settings while highlighting the potential benefits of TCI where appropriate infrastructure and expertise are available.

CONCLUSION

Both manual controlled infusion (MCI) and target controlled infusion (TCI) techniques provided effective and safe total intravenous anaesthesia with propofol and remifentanil for patients undergoing elective laparoscopic surgeries. Adequate depth of anaesthesia, satisfactory haemodynamic stability, and acceptable postoperative recovery were achieved with both methods.

Target controlled infusion was associated with lower total propofol consumption and slightly faster recovery in terms of response to verbal commands, extubation, and readiness for transfer from the operating room. However, the overall clinical differences between the two techniques were modest, and postoperative analgesic requirements were comparable.

These findings suggest that while TCI offers certain advantages in drug utilization and recovery kinetics, well-conducted manual controlled infusion remains an effective alternative with similar overall perioperative outcomes. Therefore, TCI may be preferred where appropriate equipment and expertise are available, whereas MCI continues to be a reliable and practical option in resource-limited settings.

Conflict of interest: Nil

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