Target-ControlledInfusionversus Intermittent Bolus Administration of Propofol for Sedation in Colonoscopy: A Randomized Controlled Trial

Abstract

Background: Propofolisthepreferredsedativeagentforcolonoscopy,butoptimal administration techniques remain debated. This study compared target-controlled infusion (TCI) with intermittent bolus (IB) administration regarding safety, enjcacy, and patientsatisfaction.

Methods: We conducted a prospective, randomized, single-center study of 100 patients (ASA I-III) undergoing elective colonoscopy. Patients were randomized to receive propofol via TCI (n=50) or IB administration (n=50). Primary endpoints included composite safety outcomes and sedation adjustments. Secondary endpoints comprised propofol consumption, recovery time, and satisfaction scores.

Results: The composite safety endpoint occurred in 18 (36%) TCI patients versus 19 (38%) IB patients (p=0.836). However, TCI patients experienced more hypotension (22% vs 8%, p=0.031) but less tachycardia (6% vs 20%, p=0.028) and desaturation (6% vs22%,p=0.008).TCIrequiredfewersedationadjustments(median1vs3,p<0.001) and achieved higher patient satisfaction scores (8.2±1.4 vs 7.5±1.6, p=0.017). Total propofol consumption was higher with TCI (454.0±110.8mg vs 305.9±73.1mg, p<0.001),whilstrecoverytimewaslonger(16.5±2.9minvs11.9±2.2min,p<0.001).

Conclusion: Both techniques demonstrated comparable overall safety. TCI provided superior sedation stability and patient satisfaction but required higher drug consumption and longer recovery times. Technique selection should be individualized basedonpatientcharacteristicsandclinicalpriorities.

Introduction

Colonoscopy remains the gold standard for colorectal cancer screening and surveillance, with over 14 million procedures performed annually worldwide[1]. Effective sedation is crucial for patient comfort, procedural success, and future compliance with screening recommendations[2]. Propofol has emerged as the preferred sedative agent due to its rapid onset, short duration of action, and favorable recovery profile[3].

Theadministrationtechniqueforpropofolsignificantlyinfluencesclinicaloutcomes. Traditional intermittent bolus (IB) administration, whilst simple and cost-effective, mayresultinfluctuatingplasmaconcentrationsleadingtoperiodsofinadequateor excessive sedation[4]. Target-controlled infusion (TCI) systems, utilizing pharmacokinetic models to maintain predetermined plasma concentrations, theoreticallyprovidemorestablesedationlevels[5].

Current evidence comparing TCI and IB administration for gastrointestinal endoscopy remains limited and conflicting. Whilst some studies suggest improved hemodynamic stability with TCI[6], others report increased drug consumption and prolonged recovery times[7]. The European Society of Gastrointestinal Endoscopy (ESGE) guidelines acknowledgebothtechniquesasacceptablefornon-anesthesiologistadministration ofpropofol(NAAP)[8],butprovidelimitedguidanceonoptimaltechniqueselection.

This randomized controlled trial aimed to comprehensively compare TCI and IB propofol administration for colonoscopy sedation, hypothesizing that TCI would provide superior hemodynamic stability and patient comfort whilst maintaining comparable safety profiles.

Methods

StudyDesignandParticipants

Thisprospective,randomized,single-centerstudywasconductedbetweenJanuary and December 2023 at a tertiary endoscopy unit. The study protocol received approval fromtheinstitutionalresearchethicscommittee(Reference:REC-2023-001),andall participantsprovidedwritteninformedconsent.

Inclusion criteria comprised patients aged 18-80 years with ASA physical status I-III scheduled for elective colonoscopy. Exclusion criteria included pregnancy, allergy to propofoloritscomponents,severecardiacorrespiratorydisease,bodymassindex >35kg/m²,historyofsubstanceabuse,andinabilitytoprovideinformedconsent.

RandomizationandInterventions

Participantswererandomizedusingcomputer-generatedrandomnumbersinsealed opaqueenvelopestoreceivepropofolviaeitherTCIorIBadministration.Allpatients received standardized monitoring including continuous electrocardiography, pulse oximetry, non-invasive blood pressure measurement, and capnography. Supplemental oxygen(2L/min)wasadministeredvianasalcannulae.

TCIGroup: PropofolwasadministeredusingtheMarshpharmacokineticmodelwith aninitialtargetplasmaconcentrationof2.0μg/ml,adjustedin0.5μg/mlincrements toachieveoptimalsedation(ModifiedObserver'sAssessmentofAlertness/Sedation [MOAA/S]score2-3).

IBGroup: Propofolwasadministeredasinitialbolusdosesof0.5-1.0mg/kgfollowed byincrementalbolusesof10-20mgtitratedtoachieveidenticalsedationtargets.

Allprocedureswereperformedbyexperiencedendoscopists,withsedationmanaged by trained anesthetic nurses under anesthetist supervision, consistent with ESGE guidelines for NAAP[8].

OutcomeMeasures

Primary Endpoints: Thecompositesafetyendpointincludedhypotension(systolic bloodpressure<90mmHgor>20%decreasefrombaseline),tachycardia(heartrate >100bpm),andoxygendesaturation(SpO_2<90%).Sedationenjcacywasassessedby the number of dose adjustments required during the procedure.

Secondary Endpoints: Total propofol consumption, recovery time (procedure completion to MOAA/S score 5), patient satisfaction (11-point numerical rating scale), endoscopistsatisfaction(5-pointLikertscale),andhemodynamicstability(coenjcientofvariationforheartrateandbloodpressure).

Statistical Analysis

Sample size calculation, based on a 20% difference in composite adverse events with80% power and 5% significance level, required 45 patients per group. Allowing for 10% dropout,50patientswererecruitedpergroup.Continuousvariableswereanalyzed usingStudent'st-testorMann-WhitneyUtestasappropriate.Categoricalvariables werecomparedusingchi-squareorFisher'sexacttest.Statisticalsignificancewasset atp<0.05.

Results

ParticipantCharacteristics

One hundred patients were randomized and completed the study protocol. Baseline characteristics were well-balanced between groups. Mean age was 50.7±13.6 years in theTCIgroupand53.2±12.6yearsintheIBgroup(p=0.340).Themajorityofpatients wereASAclassIorII(88%TCI,85%IB),withnosignificantdifferencesindemographic or clinical parameters.

Table1.BaselineDemographicandClinicalCharacteristics

Variable	TCIGroup(n=50)	IBGroup(n=50)	p-value
Age(years)	50.7±13.6	53.2±12.6	0.340
Weight(kg)	71.9±13.1	74.8±11.3	0.291
Height(cm)	167.9±10.6	168.1±6.5	0.798
BMI(kg/m²)	25.7±5.1	26.5±4.1	0.324
Malesex,n(%)	25(50%)	24(48%)	0.818
ASAClassI/II/III	20/24/6	18/25/7	0.112

PrimaryOutcomes

Thecompositesafetyendpointoccurredin18(36%)TCIpatientsand19(38%)IB patients (p=0.836), indicating no significant difference in overall safety. However, analysisofindividualcomponentsrevealeddistinctpatternsbetweengroups.

Hypotension was significantly more frequent in the TCI group (22% vs 8%, p=0.031, OR=3.25,95%CI:1.12-9.42).Conversely,tachycardiaoccurredlessfrequentlywithTCI (6%vs20%,p=0.028,OR=0.26,95%CI:0.08-0.85),asdidoxygendesaturation(6%vs 22%,p=0.008,OR=0.22,95%CI:0.07-0.69).

The number of sedation adjustments was significantly lower in the TCI group (median 1[IQR0-1]vs3[IQR1-4],p<0.001),supportingthehypothesisofimprovedsedation stability.

SecondaryOutcomes

Total propofol consumption was significantly higher with TCI (454.0±110.8mg vs 305.9±73.1mg, p<0.001), representing a 48% increase. When adjusted for body weight, this difference remained significant (6.4±1.6 mg/kg vs 4.1±1.0 mg/kg, p<0.001).

Recovery time was significantly longer in the TCI group (16.5±2.9 minutes vs 11.9±2.2 minutes,p<0.001),representinga39%increasethatcouldimpactpatientthroughput.

Patient satisfaction scores were significantly higher with TCI (8.2±1.4 vs 7.5±1.6, p=0.017),aswereendoscopistsatisfactionscores(4.3±0.7vs4.0±0.8,p=0.045).

Table2.PrimaryandSecondaryOutcomes

Variable	TCIGroup(n=50)	IBGroup(n=50)	p-value
PrimaryEndpoints			
Compositeadverseevents	18(36%)	19(38%)	0.836
Hypotension	11(22%)	4(8%)	0.031
Tachycardia	3(6%)	10(20%)	0.028
Desaturation	3(6%)	11(22%)	0.008
Sedationadjustments	1(0-1)	3(1-4)	<0.001
SecondaryEndpoints			
Totalpropofoldose(mg)	454.0±110.8	305.9±73.1	<0.001
Recoverytime(min)	16.5±2.9	11.9±2.2	<0.001
Patientsatisfaction	8.2±1.4	7.5±1.6	0.017
Endoscopistsatisfaction	4.3±0.7	4.0±0.8	0.045

HemodynamicStability

TCIdemonstratedsuperiorhemodynamicstability,withsignificantlylowercoenjcientsof variation for mean arterial pressure (12.3% vs 18.7%, p=0.002) and heart rate (8.9% vs 13.4%, p=0.001). This improved stability translated to more predictable cardiovascularresponsesthroughouttheprocedure.

SubgroupAnalysis

In patients aged ‘‘65 years (n=28), TCI benefits were more pronounced, with greater reductions in tachycardia (0% vs 25%, p=0.045) and improved satisfaction scores. Similarly,patientswithASAclassIIIdemonstratedfewercompositeadverseevents with TCI (33% vs 71%, p=0.048).

Discussion

Thisrandomizedcontrolledtrialprovidescomprehensiveevidencecomparing TCIand IB propofol administration for colonoscopy sedation. Whilst both techniques demonstrated comparable overall safety, they exhibited distinct profiles regarding hemodynamicstability,drugconsumption,andpatientexperience.

SafetyandEfficacy

Thesimilarcompositesafetyendpointsbetweengroupsconfirmthatbothtechniques canbesafelyadministeredwhenappropriateprotocolsareemployed.However,the differentialpatternofindividualadverseeventsprovidesimportantclinicalinsights. The increased hypotension with TCI likely reflects more consistent drug delivery achieving sustained plasma concentrations that may predispose to cardiovascular depression[9]. Conversely, the reduced tachycardia and desaturation suggest more effectivebluntingofsympatheticresponsesandbetterrespiratorystability[10].

The significantly fewer sedation adjustments required with TCI (median 1 vs 3) providesobjectiveevidenceofimprovedsedationstability.Thisfindinghaspractical implications for nursing workload and procedural enjciency, particularly in high- volume endoscopy units.

DrugConsumptionandRecovery

The 48% increase in propofol consumption with TCI represents a significant economic consideration. This finding is consistent with previous studies and reflects the continuous drug delivery inherent to TCI systems[11]. However, this increased consumption must be balanced against improved patient satisfaction and reduced adverseevents.

The prolonged recovery time with TCI (39% increase) could impact patient throughput,particularlyinresource-constrainedsettings.Thisfindinglikelyreflects higher cumulative drug exposure and warrants consideration in clinical decision- making.

PatientandProviderSatisfaction

The improved patient satisfaction with TCI, whilst statistically significant, represents a modest absolute difference. However, in the context of patient-centered care and future screening compliance, this improvement may have meaningful clinical significance.Similarly,enhancedendoscopistsatisfactionsuggestsbetterprocedural conditionsthatcouldpotentiallyimproveexaminationquality.

ClinicalImplications

Our findings suggest that technique selection should be individualized based on patient characteristics and clinical priorities. TCI may be preferred for elderly patients, those with significant comorbidities, or complex procedures where hemodynamic stabilityisparamount.Conversely,IBadministrationmaybeappropriateforroutine proceduresinhealthypatientswhererapidturnoverisessential.

Limitations

Several limitations warrant acknowledgment. The single-center design may limit generalizabilitytootherclinicalsettings.Theinabilitytoblindtheanesthetistcould introducebias,thoughstandardizedprotocolsandobjectiveoutcomeshelpmitigate this concern. Additionally, our study focused on short-term outcomes and did not assesslonger-termeffectsonpatientsatisfactionorprocedureacceptance.

FutureResearch

Futurestudiesshouldexplorehybridapproachescombiningtheadvantagesofboth techniques,investigatetheroleofprocessedelectroencephalographymonitoringin optimizingsedationdelivery,andconductcomprehensivehealtheconomicanalyses to guide policy decisions.

Conclusion

This randomized controlled trial demonstrates that both TCI and IB propofol administrationaresafeandeffectiveforcolonoscopysedation.TCIprovidessuperior hemodynamicstability,reducedadverseevents,andimprovedpatientsatisfaction, butatthecostofincreaseddrugconsumptionandprolongedrecoverytimes.The

choicebetweentechniquesshouldbeindividualizedbasedonpatientcharacteristics, procedural complexity, and institutional resources. These findings contribute important evidence to guide clinical decision-making and support the continued evolutionofsedationpracticesingastrointestinalendoscopy.

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