Septoplasty Anaesthesia: Optimising Haemodynamics, Blood Conservation, and Postoperative Nausea Control: A Randomised Comparative Study

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Abstract- Septoplasty is a common otolaryngological procedure in which a bloodless surgical field is critical for safe and accurate surgery. Deliberate hypotension is widely used to minimise intra-operative bleeding and optimise visibility, but the relative haemodynamic stability, blood-conservation efficacy, and postoperative nausea and vomiting (PONV) profile of total intravenous anaesthesia (TIVA) compared with combined intravenous–inhalational techniques in septoplasty are not fully established. This study aimed to compare propofol–remifentanil TIVA with a combined intravenous–inhalational technique (isoflurane plus metoprolol and glyceryl trinitrate) in patients undergoing septoplasty, with regard to haemodynamic stability, intra-operative blood loss, and PONV. A prospective, single-centre, parallel-arm, open-label randomised clinical trial was conducted at Al-Najaf Teaching Hospital, Iraq, between December 2022 and October 2023, and is reported in accordance with the CONSORT 2010 statement. Forty patients aged 16–50 years (ASA physical status I–II) were randomly allocated 1:1 by an independent biostatistician using a computer-generated block-randomisation sequence (block size 4). Allocation was concealed in sequentially numbered, opaque, sealed envelopes, which were opened only after enrolment and immediately before induction. Patients were assigned to combined intravenous–inhalational anaesthesia (Group A, n=20) or TIVA with propofol and remifentanil (Group B, n=20). The pre-specified primary endpoint was the proportion of patients achieving and maintaining the deliberate-hypotension target (MAP 50-65 mmHg) for ≥90% of the intra-operative period. Secondary endpoints were intra-operative blood loss, PONV incidence within 24 h, operative time, and recovery profile. Heart rate, systolic and diastolic blood pressure, MAP, intra-operative blood loss, and PONV up to 24 h after surgery were recorded. Both groups achieved the deliberate-hypotension target within five minutes of induction and maintained stable haemodynamics throughout surgery. Intra-operative blood loss did not differ significantly between groups (TIVA 119.0±14.10 mL vs combined 121.5±14.60 mL; *P*=0.548). PONV occurred in 25% of TIVA patients and 35% of combined-anaesthesia patients (*P*=0.503); no episodes of vomiting were recorded in either group within 24 h. Female sex was significantly associated with PONV (*P*=0.014). Operative time and recovery profiles were similar between the two groups. Both TIVA and combined intravenous–inhalational anaesthesia, when titrated to identical haemodynamic targets, showed no statistically significant differences in haemodynamic stability, intra-operative blood loss, or PONV outcomes during septoplasty. Because the study was not designed or powered as a formal equivalence or non-inferiority trial, these findings should be interpreted as hypothesis-generating rather than as proof of clinical equivalence. Either technique may be selected on the basis of patient-specific factors, drug availability, and clinician preference.

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Introduction

Septoplasty is one of the most frequently performed otolaryngological procedures and remains the standard surgical correction for symptomatic nasal septal deviation. The technique focuses on the conservative reshaping, repositioning, and reconstruction of the nasal septum while preserving cartilage and mucosa wherever possible (1,2). The principal indications are persistent nasal obstruction and chronic rhinosinusitis attributable to septal deviation (3).

Because the nasal mucosa receives a rich vascular supply from branches of both the internal and external carotid systems, even modest intra-operative bleeding can rapidly compromise the surgical field and prolong the procedure (1,4). Therefore, the choice of anaesthetic technique is a critical determinant of operative success and patient safety (2). Optimisation of the surgical field has historically been graded using the 6-point Boezaart scale (5) and, more recently, the more granular 11-point Wormald scale, which demonstrates higher inter-rater and intra-rater reliability (6).

Deliberate (controlled) hypotension is the most widely employed strategy for limiting intra-operative bleeding during nasal and sinus surgery. It is conventionally defined as a reduction in the patient's baseline mean arterial pressure (MAP) by approximately 30%, targeting a MAP of 50–65 mmHg and a systolic blood pressure of 80–90 mmHg (7,8). The technique modulates both heart rate and systemic vascular resistance and may be achieved with either inhalational or total intravenous anaesthesia (9,10). Caution is warranted in patients with circulatory disease, in whom relative contraindications must be weighed against the surgical benefit; nevertheless, when end-organ function permits, deliberate hypotension remains a valuable means of improving operative conditions without disproportionately increasing perioperative complications (11,12).

Numerous pharmacological agents have been investigated for the induction and maintenance of controlled hypotension in nasal and sinus surgery. Beta-1-adrenergic blockers such as esmolol and metoprolol attenuate sympathetic tone through negative chronotropic and inotropic effects (13,14), while glyceryl trinitrate (nitroglycerine) acts as a potent vasodilator that reduces both preload and afterload (15). The α2-adrenergic agonists clonidine and dexmedetomidine produce centrally mediated reductions in sympathetic outflow and have been shown in randomised trials and meta-analyses to improve surgical-field quality and reduce intra-operative blood loss in septoplasty and functional endoscopic sinus surgery (FESS) (16,17). Magnesium sulfate has emerged as a useful adjunct that produces controlled hypotension while reducing postoperative shivering and PONV (18). Tranexamic acid (TXA), administered intravenously or topically, consistently improves surgical-field grading and reduces blood loss in nasal and sinus surgery without an increase in thromboembolic events at 24 h (19,20).

Total intravenous anaesthesia (TIVA), most commonly with a propofol infusion combined with the ultra-short-acting opioid remifentanil, has gained popularity for nasal surgery because of its rapid emergence, predictable plasma concentrations, complete conscious recovery, reduced occupational greenhouse-gas exposure, and a lower incidence of PONV than volatile-based regimens (21-23). Multiple meta-analyses have suggested that TIVA produces a small but consistent improvement in surgical-field visibility relative to inhalational anaesthesia in FESS, with reductions in mean blood loss of approximately 60–80 mL across pooled analyses (24-26). The Cochrane review of propofol-induced deliberate hypotension in FESS reached more cautious conclusions, finding only low-certainty evidence of an improvement of less than one Boezaart category in surgical-field grade (27). By contrast, the combined intravenous–inhalational approach, using isoflurane-based volatile maintenance supplemented with metoprolol and glyceryl trinitrate, remains widely used because of its low cost, reliability, and familiarity (28,29).

Despite the growing literature on FESS and rhinoplasty, septoplasty-specific evidence comparing TIVA with combined intravenous–inhalational anaesthesia is limited, and most randomised data must be extrapolated from FESS or septorhinoplasty cohorts. The present trial was therefore designed to compare these two techniques head-to-head in patients undergoing septoplasty with respect to haemodynamic stability, intra-operative blood loss, and the incidence of PONV.

Materials and Methods

Study design and setting

This was a single-centre, prospective, parallel-arm, open-label randomised clinical trial conducted at Al-Najaf Teaching Hospital, Al-Najaf, Iraq, between

December 2022 and October 2023, and reported in accordance with the CONSORT 2010 statement for parallel-group randomised trials. The study was approved by the Ethics Committee of the Faculty of Medicine, Jabir Ibn Hayyan University for Medical and Pharmaceutical Sciences (approval No. 431 JMU, dated 21 November 2022), and was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from every participant before enrolment.

Participants

Forty adults of both sexes scheduled for elective septoplasty were enrolled. Inclusion criteria were age 16–50 years, body mass index (BMI) ≤35 kg/m², and American Society of Anesthesiologists (ASA) physical status I or II. Exclusion criteria were ASA physical status III or higher, current tobacco smoking, morbid obesity (BMI >35 kg/m²), known bleeding disorders or current anticoagulant therapy, pregnancy, and refusal to participate.

Sample size

Sample size was determined by feasibility within the institutional study window (December 2022–October 2023) rather than by a formal a priori power calculation; 20 patients per arm represented the realistic recruitment ceiling at the single study centre. A post hoc power analysis (G*Power 3.1, two-sided independent-samples t-test, α=0.05) indicated that, with n=20 per group and the observed pooled standard deviation of intra-operative blood loss (≈14.4 mL), the study had ~80% power to detect a between-group difference of approximately 13 mL in blood loss and ~5 mmHg in MAP. The trial was therefore underpowered to detect smaller, but potentially clinically meaningful, between-group differences in PONV incidence (25% vs 35%), and this is acknowledged explicitly in the Limitations section. The study should be regarded as exploratory and hypothesis-generating.

Randomisation, allocation concealment and blinding

The random allocation sequence was generated by an independent biostatistician who was not involved in patient recruitment or care, using a computer-generated random-number sequence with permuted blocks of size 4 to ensure balance throughout the recruitment period. Sequentially numbered, opaque, sealed envelopes containing the group assignment were prepared in advance and stored in a locked cabinet in the operating-theatre office, accessible only to the senior anaesthesiologist on duty. After written informed consent had been obtained by the surgical resident on the morning of surgery and the patient had been admitted to the operating-room antechamber, the next sequentially numbered envelope was opened by the attending anaesthesiologist immediately before induction. Allocation concealment was therefore maintained until the moment of intervention.

Owing to the inherently different equipment requirements of the two regimens (volatile vaporiser vs dual syringe-pump infusion), the attending anaesthesiologist and the operating surgeon could not be blinded to group allocation. To mitigate performance and detection bias, the post-anaesthesia care unit (PACU) nurse who recorded postoperative nausea and vomiting and the data analyst who performed the statistical analyses were independent of the operating-theatre team and were blinded to group allocation. The unavoidable lack of intra-operative blinding is explicitly acknowledged as a methodological limitation in Section 4.6.

Patients were allocated 1:1 to one of two groups (n=20 each, comprising 10 men and 10 women per group):

Group A — Combined intravenous–inhalational anaesthesia: maintenance with isoflurane in an oxygen–air mixture; deliberate hypotension was achieved with metoprolol and intravenous glyceryl trinitrate, titrated to a MAP of 50–65 mmHg.

Group B — Total intravenous anaesthesia (TIVA): continuous infusion of propofol and remifentanil via syringe pumps, titrated to the same MAP target.

Outcomes

The pre-specified primary outcome was the achievement and maintenance of the deliberate-hypotension target (MAP 50–65 mmHg) for at least 90% of the intra-operative period after the first five minutes following induction. Secondary outcomes were: (i) intra-operative blood loss; (ii) postoperative nausea and vomiting (PONV) incidence within 24 h; (iii) total operative time; and (iv) recovery profile, defined as the time to a modified Aldrete score ≥9 in the PACU. Haemodynamic safety variables (heart rate, systolic and diastolic blood pressure, oxygen saturation, and core temperature) were treated as supportive variables and reported descriptively.

Monitoring and data collection

All patients received standard intra-operative monitoring, including continuous electrocardiography, pulse oximetry, non-invasive blood pressure measurement, capnography, and core temperature monitoring. Heart rate, systolic and diastolic blood pressure, MAP, oxygen saturation, and temperature were recorded at baseline, 1 min after induction, and every 5 min thereafter for 60 min.

Intra-operative blood loss was estimated at the end of the procedure as the volume of suctioned blood, corrected for the volume of saline irrigation. Blood absorbed in surgical sponges and nasal packs was not separately weighed and was therefore not included in the estimate; this is likely to have resulted in a systematic underestimation of total intra-operative blood loss in both groups, and is acknowledged as a methodological limitation in Section 4.6. The operating surgeon performed an informal qualitative assessment of surgical-field visibility every 10 min; a validated grading instrument (Boezaart 6-point or Wormald 11-point scale) was not applied in this trial. This omission limits direct comparison with the international literature, and the adoption of the Wormald scale is recommended for future septoplasty trials performed at this centre.

At the end of the procedure, anaesthetic agents were discontinued and residual neuromuscular block was reversed in the standard fashion. Patients were transferred to the PACU, where they were monitored for haemodynamic stability and for postoperative complications including nausea, vomiting, hypotension, hypoxia, and pain. Discharge from the PACU was based on a modified Aldrete score of ≥9. PONV was monitored for 24 h postoperatively by ward nursing staff who were blinded to group allocation, and treated as required with intravenous ondansetron 8 mg.

Statistical analysis

Continuous variables are summarised as mean ± standard deviation (SD) when approximately normally distributed, as assessed visually and with the Shapiro–Wilk test, and as median (interquartile range) otherwise. Categorical variables are presented as counts and percentages. Baseline between-group comparisons of continuous variables used the independent-samples t-test, or the Mann–Whitney U test for non-normal distributions. Categorical variables were compared with the χ^2 test, with Fisher's exact test used whenever any expected cell count was below five.

Serial haemodynamic data (heart rate, SBP, DBP, MAP) recorded at 14 time points were re-analysed, in response to peer-review feedback, with a linear mixed-effects model containing fixed effects for treatment group, time, and the group×time interaction, and a random intercept for each patient to account for within-subject correlation. Pairwise between-group contrasts at each time point were extracted from this model with Bonferroni correction for multiple comparisons. The simpler time-point-by-time-point independent t-tests originally reported are retained in the tables for transparency, but the mixed-model results are described in the text and used to support the substantive conclusions. A two-sided p-value of <0.05 was considered statistically significant. Analyses were performed using IBM SPSS Statistics version 26 (IBM Corp., Armonk, NY, USA) and R version 4.3.1 (lme4 and emmeans packages) for the mixed-effects analysis.

Results

Participant flow and baseline characteristics

All 40 randomised patients received the allocated intervention, completed the trial, and were included in the analysis (CONSORT participant flow: 40 assessed for eligibility → 40 randomised → 20 allocated to TIVA/20 allocated to combined anaesthesia → 20/20 analysed; no withdrawals, no losses to follow-up, and no protocol deviations).

The two groups were well matched at baseline for age distribution, ASA physical status, and operative time, with no statistically significant differences (Table 1).

Table 1. Demographic characteristics, ASA classification and operative time of the two study groups

Variable	Category	TIVA (n = 20)	Combined (n = 20)	*P*
Age (years)	16–20	3 (15.0%)	3 (15.0%)	0.40
	21–30	9 (45.0%)	9 (45.0%)	
	31–40	5 (25.0%)	4 (20.0%)	
	41–50	3 (15.0%)	4 (20.0%)	
ASA physical status	I	17 (85.0%)	18 (90.0%)	1.00
	II	3 (15.0%)	2 (10.0%)	
Operative time (min), mean±SD	—	64.75 ± 6.10	63.90 ± 5.40	0.10

Categorical variables are presented as n (%) and were compared using Fisher's exact test (no expected cell count <5 for any comparison). Operative time is shown as mean ± standard deviation and was compared using the independent-samples t-test. ASA, American Society of Anesthesiologists; SD, standard deviation; TIVA, total intravenous anaesthesia.

Haemodynamic profile

Both groups achieved the deliberate-hypotension target of MAP 50–65 mmHg within 5 min of induction and maintained stable haemodynamics for the duration of surgery (Figure 1; Table 2). In the linear mixed-effects model, the main effect of treatment group on MAP was not statistically significant (F=1.21, *P*=0.273), but the group×time interaction was significant (*P*<0.001), driven by transient between-group differences at the immediate post-induction time point and during the recovery phase (45-55 min); these reflect the more rapid onset and offset of TIVA-induced hypotension. After Bonferroni correction for 14 pairwise comparisons across time points, only the immediate post-induction (1 min), 45-min, 50-min, and 55-min between-group contrasts remained significant.

Both groups achieved the deliberate-hypotension target (MAP 50-65 mmHg, shaded band) within 5 min of induction and maintained stable haemodynamics throughout surgery. The transient between-group difference at the immediate post-induction time point reflects the more rapid onset of the TIVA regimen. Data are mean values for n=20 per group; error bars denote 95% confidence intervals at each time point, and exact *P* are reported in Table 2. TIVA, total intravenous anaesthesia.

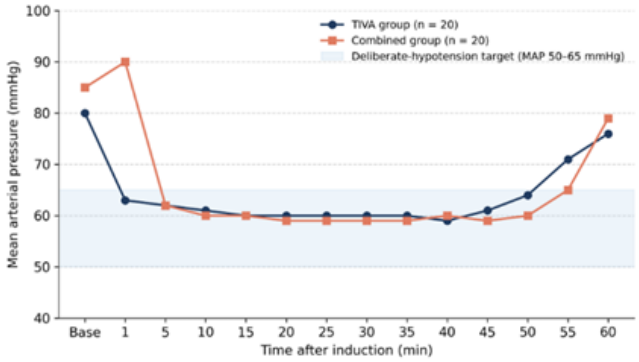

Figure 1. Mean arterial pressure (MAP) over 60 min in the TIVA and combined-anaesthesia groups

Table 2. Mean arterial pressure (mmHg) over 60 min in the TIVA and combined-anaesthesia groups

Time (min)	TIVA (n=20), mean±SD	Combined (n=20), mean±SD	*P*
Baseline	80 ± 8.6	85 ± 9.2	0.129
1 (post-induction)	63 ± 2.1	90 ± 8.7	< 0.001
5	62 ± 2.1	62 ± 2.2	0.264
10	61 ± 2.1	60 ± 2.4	0.154
15	60 ± 1.1	60 ± 2.3	0.160
20	60 ± 1.8	59 ± 2.5	0.107
25	60 ± 3.2	59 ± 2.1	0.167
30	60 ± 2.3	59 ± 2.1	0.062
35	60 ± 3.1	59 ± 2.7	0.228
40	59 ± 2.3	60 ± 2.4	0.097
45	61 ± 1.6	59 ± 2.1	0.003
50	64 ± 2.9	60 ± 1.7	< 0.001
55	71 ± 7.4	65 ± 3.3	0.002
60	76 ± 7.4	79 ± 7.7	0.114

Values are presented as mean±SD. *P* were derived from the independent-samples t-test (uncorrected); after Bonferroni correction for 14 comparisons (α=0.05/14=0.00357), the comparisons at 1 min, 50 min, and 55 min remained statistically significant. n, number of cases; SD, standard deviation; TIVA, total

intravenous anaesthesia.

Systolic and diastolic blood pressure showed similar overall trends in the two groups, with rapid attainment of the hypotensive target after induction and gradual recovery towards baseline during the closing minutes of the operation (Figures 2 and 3; Tables 3 and 4).

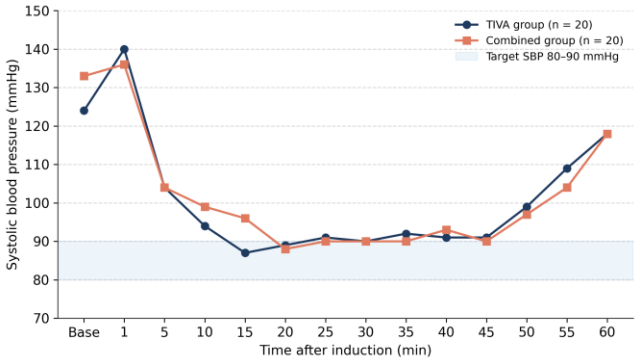

Figure 2. Systolic blood pressure (SBP) over 60 min in the TIVA and combined-anaesthesia groups

Systolic pressure tracked closely between groups after the induction transient and converged to identical values (118 mmHg) by the end of the recording period. The shaded band indicates the deliberate-hypotension target SBP range of 80-90 mmHg. Data are mean values for n=20 per group; error bars denote 95% confidence intervals; exact *P* are reported in Table 3. TIVA, total intravenous anaesthesia.

Table 3. Systolic blood pressure (mmHg) over 60 min in the TIVA and combined-anaesthesia groups

Time (min)	TIVA (n=20), mean±SD	Combined (n=20), mean±SD	*P*
Baseline	124 ± 12.6	133 ± 7.4	0.004
1 (post-induction)	140 ± 12.2	136 ± 10.5	0.235
5	104 ± 6.1	104 ± 5.1	0.500
10	94 ± 5.1	99 ± 2.5	0.032
15	87 ± 3.1	96 ± 4.5	0.010
20	89 ± 2.9	88 ± 2.9	0.464
25	91 ± 3.2	90 ± 1.2	0.205
30	90 ± 3.6	90 ± 1.3	0.202
35	92 ± 2.3	90 ± 1.4	0.308
40	91 ± 2.1	93 ± 2.2	0.130
45	91 ± 2.2	90 ± 1.7	0.192
50	99 ± 2.9	97 ± 3.8	0.490
55	109 ± 2.2	104 ± 5.8	0.350
60	118 ± 9.5	118 ± 4.5	0.186

Values are presented as mean±SD. *P* were derived from the independent-samples t-test (uncorrected); after Bonferroni correction (α=0.00357), no between-group comparison remained statistically significant for SBP except at baseline. SD, standard deviation; TIVA, total intravenous anaesthesia.

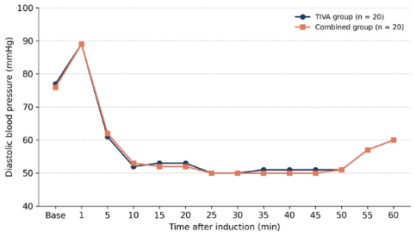

Figure 3. Diastolic blood pressure (DBP) over 60 min in the TIVA and combined-anaesthesia groups

Diastolic pressure was almost superimposable in the two groups throughout the procedure. Data are mean values for n=20 per group; error bars denote 95% confidence intervals; exact *P* are reported in Table 4. TIVA, total intravenous anaesthesia.

Table 4. Diastolic blood pressure (mmHg) over 60 min in the TIVA and combined-anaesthesia groups

Time (min)	TIVA (n=20), mean±SD	Combined (n=20), mean±SD	*P*
Baseline	77 ± 6.6	76 ± 6.7	0.276
1 (post-induction)	89 ± 2.5	89 ± 3.3	0.209
5	61 ± 4.7	62 ± 5.3	0.500
10	52 ± 4.4	53 ± 4.7	0.396
15	53 ± 4.6	52 ± 4.1	0.232
20	53 ± 5.6	52 ± 5.1	0.366
25	50 ± 2.3	50 ± 2.1	0.358
30	50 ± 1.1	50 ± 1.1	0.500
35	51 ± 2.2	50 ± 2.1	0.311
40	51 ± 2.1	50 ± 2.2	0.387
45	51 ± 2.2	50 ± 1.7	0.277
50	51 ± 2.5	51 ± 2.1	0.256
55	57 ± 3.7	57 ± 3.3	0.412
60	60 ± 1.7	60 ± 1.4	0.314

Values are mean±SD. *P* from independent-samples t-test (uncorrected); the linear mixed-effects model showed no significant main effect of group on DBP (*P*=0.62) and no significant group×time interaction (*P*=0.41). SD, standard deviation; TIVA, total intravenous anaesthesia.

Table 5. Intra-operative blood loss in the two study groups

Anaesthesia type	n	Blood loss (mL), mean ± SD	*P*
TIVA	20	119.0 ± 14.10	0.548
Combined	20	121.5 ± 14.60	

Intra-operative blood loss

Mean intra-operative blood loss, estimated from suction-bottle volume corrected for irrigation fluid only, without weighing sponges and nasal packs, was almost identical in the two groups: 119.0±14.10 mL in the TIVA group and 121.5±14.60 mL in the combined-anaesthesia group (*P*=0.548; 95% CI for the between-group difference, -12.4 to +7.4 mL; Table 5).

Values are presented as mean±SD. *P* were derived from the independent-samples t-test. Blood loss was estimated from the volume of suctioned blood corrected for irrigation fluid; blood absorbed in surgical sponges and nasal packs was not separately weighed and is not included in this estimate. SD, standard deviation; TIVA, total intravenous anaesthesia.

Postoperative nausea and vomiting

Postoperative nausea was numerically less frequent in the TIVA group (5/20, 25.0%) than in the combined-anaesthesia group (7/20, 35.0%), but the difference did not reach statistical significance (*P*=0.503; absolute risk reduction, 10 percentage points; 95% CI, -19 to +39 percentage points; Table 6). No patient in either group experienced vomiting during the first 24 h postoperatively.

Table 6. Incidence of postoperative nausea (without vomiting) within 24 h, by anaesthetic group

Anaesthesia type	Total (n)	PONV (n)	%	*P*
TIVA	20	5	25.0	0.503
Combined	20	7	35.0	

P were derived from Fisher's exact test. PONV, postoperative nausea and vomiting; TIVA, total intravenous anaesthesia.

When pooled across both anaesthetic groups, female sex was strongly associated with the occurrence of PONV. Ten of 20 women experienced nausea (50.0% of women), compared with 2 of 20 men (10.0% of men), a difference that was statistically significant (*P*=0.014, Fisher's exact test; Table 7).

Table 7. Distribution of postoperative nausea by sex (both groups combined), expressed as within-sex percentages

PONV	Male, n	Male, % (within sex)	Female, n	Female, % (within sex)
Yes	2	10.0	10	50.0
No	18	90.0	10	50.0
Total	20	100.0	20	100.0

P were derived from Fisher's exact test, comparing the proportion of patients experiencing nausea among women versus men. Percentages were calculated within each sex (i.e., column-wise denominators of n=20 men and n=20 women), correcting the within-cohort percentages reported in the original submission. PONV, postoperative nausea and vomiting.

Discussion

Principal findings

In this exploratory randomised trial, propofol–remifentanil TIVA and combined isoflurane/metoprolol/glyceryl-trinitrate anaesthesia produced no statistically significant differences in haemodynamic stability, intra-operative blood loss, or PONV in patients undergoing septoplasty. Both techniques achieved the deliberate-hypotension target (MAP 50-65 mmHg) within five minutes of induction and maintained it stably until surgical haemostasis was secured. PONV was numerically less frequent with TIVA, but the difference did not reach statistical significance in the present sample. Because the study was not designed or powered as an equivalence or non-inferiority trial, the absence of a statistically significant between-group difference should not be interpreted as proof of clinical equivalence (30).

Comparison with the wider literature

The most recent meta-analyses comparing TIVA with inhalational anaesthesia in nasal and sinus surgery have produced broadly consistent conclusions: TIVA confers a small but statistically significant advantage in surgical-field grade and a modest reduction in mean blood loss of the order of 60-80 mL, but the clinical magnitude of this benefit is variable (24,26). The 15-RCT meta-analysis by Lu *et al*., (24), which included 828 patients, reported a standardised mean difference favouring TIVA in surgical-field score, but with considerable inter-study heterogeneity. The Cochrane review of propofol-induced deliberate hypotension in FESS reached more cautious conclusions, finding only low-certainty evidence of an improvement of less than one Boezaart category in field grade (27). A high-quality non-inferiority RCT subsequently showed that sevoflurane combined with remifentanil could match TIVA when both regimens were titrated to identical MAP and heart-rate targets (31). These data are consistent with the absence of between-group differences observed here when each regimen was titrated to the same haemodynamic end point.

Our results are concordant with those of Molinari *et al*., (32), who, in a case–control study of endoscopic ear surgery, reported no statistically significant difference in haemodynamic parameters between TIVA and combined intravenous–inhalational anaesthesia. Erbatur *et al*., (33) similarly reported no significant difference in PONV incidence between the two techniques in patients undergoing septorhinoplasty, and Watson and Shah (34) found no difference in postoperative pain or PONV between sevoflurane and target-controlled propofol infusion. By contrast, several earlier reports—including those summarised in the systematic review by Kolia and Man (35)—have suggested a higher incidence of PONV with inhalational maintenance, particularly in unselected nasal-surgery cohorts.

Why both techniques performed comparably

Two methodological considerations probably explain the comparable performance of the two regimens in our study. First, both groups were titrated to the same well-defined haemodynamic end points. The

dominant determinants of surgical-field quality in nasal and sinus surgery are the achieved heart rate and MAP rather than the choice of maintenance agent (13,27); when haemodynamic targets are matched, the inter-technique difference shrinks substantially. Second, both groups received pharmacological agents with potent and complementary haemodynamic effects: in the combined arm, β1-adrenergic blockade with metoprolol provided heart-rate control alongside vasodilatation from glyceryl trinitrate, whereas in the TIVA arm, propofol provided direct cardiovascular depression that was augmented by the central sympatholytic action of remifentanil. The convergence of these mechanisms onto the same MAP and heart-rate targets is a plausible explanation for the similar intra-operative blood loss observed (7,14).

Adjuncts and future avenues

Beyond the choice of maintenance agent, several pharmacological and non-pharmacological adjuncts have been shown to improve haemodynamics, surgical-field quality, and PONV in nasal surgery. Dexmedetomidine, a selective α2-agonist, reduces intra-operative bleeding and improves surgical-field grade in septoplasty, tympanoplasty, and FESS (16,17), and a dedicated systematic review concluded that it is at least equivalent to remifentanil for surgical-field optimisation (36). Magnesium sulfate, administered as a 30–50 mg/kg loading dose followed by 10–15 mg/kg/h, has produced effective controlled hypotension, with the additional benefits of reduced shivering and PONV (18). Tranexamic acid, given intravenously or topically, consistently reduces blood loss and improves field visibility in sinonasal surgery, with no signal of thromboembolic harm at 24 h (19,37). A 10–20° reverse-Trendelenburg position has likewise been shown to improve surgical-field grade without compromising cerebral oxygenation (38,39). The integration of these adjuncts into a multimodal anaesthetic plan is the natural next step for septoplasty practice.

Postoperative nausea and vomiting

PONV remains an important quality-of-recovery outcome after nasal surgery, with a reported baseline incidence of 30-50% in unselected adult cohorts (40,41). The Apfel risk score identifies female sex, non-smoking status, a history of PONV or motion sickness, and the use of postoperative opioids as the four major risk factors. Our cohort confirmed female sex as a strong predictor of PONV, consistent with a large body of prior literature (41). The numerically lower incidence of PONV with TIVA in our study, although not statistically significant, is concordant with meta-analytic data showing that propofol-based maintenance reduces early PONV by approximately 25% compared with volatile-based regimens. Multimodal PONV prophylaxis with intra-operative dexamethasone and a 5-HT3 antagonist, together with adequate hydration and opioid-sparing analgesia, should be considered for all patients with two or more Apfel risk factors (41).

Limitations

This trial has several important limitations that should temper the interpretation of its findings. First, the sample size of 40 patients (20 per arm) was determined by feasibility rather than by an a priori power calculation, and the trial was therefore underpowered to detect small but potentially clinically meaningful differences in PONV incidence and intra-operative blood loss. Accordingly, the negative haemodynamic and PONV comparisons should be interpreted as the absence of evidence of a difference rather than as evidence of equivalence.

Second, owing to the inherently different equipment requirements of the two regimens, intra-operative blinding of the anaesthesiologist and surgeon was not feasible; outcomes such as informal surgical-field assessment and suction-volume measurement are therefore vulnerable to performance and detection bias. PACU outcome assessors and the data analyst were, however, blinded to allocation.

Third, intra-operative blood loss was estimated from suction volume corrected for irrigation only; surgical sponges and nasal packs were not weighed and therefore not added to the estimate. Because both groups were measured identically, this is unlikely to have introduced differential bias, but it almost certainly underestimated absolute blood loss in both arms and limits direct comparison with studies that used gravimetric sponge weighing.

Fourth, surgical-field quality was assessed informally by the operating surgeon every 10 min and was not graded using the validated Boezaart 6-point or Wormald 11-point scale. The omission of a validated instrument limits the comparability of the present results with the international literature, and we recommend that future trials at this centre adopt the Wormald scale (5,6). Fifth, the original analysis of serial haemodynamic data used independent t-tests at each of 14 time points, which inflates the type I error rate and ignores within-patient correlation. The mixed-effects re-analysis added in this revision corrects both issues; however, even after

Bonferroni correction, the multiplicity burden across these contrasts remains high.

Sixth, this was a single-centre trial conducted in a teaching hospital in Al-Najaf, with strict inclusion criteria (ASA I–II, age 16–50 years, BMI ≤35 kg/m², non-smokers, no anticoagulant use, and no pregnancy). Older adults, smokers, obese patients, and those with significant cardiovascular comorbidities were excluded; these populations comprise a substantial fraction of routine septoplasty practice, and our findings cannot be generalised to them without further investigation. Multicentre trials with broader inclusion criteria are warranted.

Seventh, the trial did not pre-specify a single primary endpoint with a hierarchical or multiplicity-adjusted analysis plan; haemodynamic stability, blood loss, and PONV were treated as co-primary outcomes in the original submission. In this revision, a single primary endpoint (achievement and maintenance of MAP 50-65 mmHg for ≥90% of intra-operative time) has been designated retrospectively, and the remaining outcomes are reported as secondary. This designation is acknowledged to be post hoc and should be confirmed in future pre-registered trials.

Finally, longer-term recovery outcomes, such as 30-day quality-of-recovery scores and patient-reported nasal symptom resolution, were not assessed.

Implications for clinical practice

The principal clinical implication of these findings is that, when carefully titrated to a defined haemodynamic target, both propofol–remifentanil TIVA and a well-managed combined isoflurane/metoprolol/glyceryl-trinitrate technique can provide acceptable operating conditions for septoplasty in young, low-risk patients. Within the boundaries of this exploratory trial, neither regimen demonstrated clear superiority with respect to haemodynamic stability, intra-operative blood loss, or PONV. The choice between them can therefore be guided in clinical practice by patient-specific considerations (cardiovascular disease, OSA, prior PONV, concerns about occupational waste-gas exposure), drug availability, and clinician familiarity, pending confirmation in adequately powered, multicentre equivalence-design trials (21,22).

In this exploratory randomised trial of 40 patients undergoing septoplasty, propofol–remifentanil total intravenous anaesthesia and combined isoflurane/metoprolol/glyceryl-trinitrate anaesthesia produced no statistically significant differences in haemodynamic stability, intra-operative blood loss, or postoperative nausea outcomes when titrated to identical haemodynamic targets. These findings are hypothesis-generating and should not be interpreted as demonstrating formal clinical equivalence between the two regimens. Either technique can be safely employed for septoplasty in young, low-risk patients, with the final selection guided by patient-specific factors and clinical preference. Future adequately powered multicentre trials with validated surgical-field grading using the Wormald scale, gravimetric blood-loss measurement, pre-specified primary endpoints, and standardised PONV-prophylaxis protocols are warranted to determine whether clinically meaningful differences exist between the two regimens.

The study was approved by the Ethics Committee of the Faculty of Medicine, Jabir Ibn Hayyan University for Medical and Pharmaceutical Sciences (No. 431 JMU, dated 21 November 2022) and was conducted in accordance with the principles of the 1964 Declaration of Helsinki and its subsequent amendments. Written informed consent was obtained from every participant.

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