

Sevoflurane versus isoflurane in shoulder arthroscopy in beach chair position in patients with prior interscalene brachial plexus block: A prospective randomised equivalency-based haemodynamic evaluation trial

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ABSTRACT

Background and Aims: There is a paucity of literature on comparative effects of different inhalational anaesthetics in beach chair position (BCP) for shoulder arthroscopy. We aimed to investigate and compare the haemodynamic effects, anaesthetic and surgical outcomes between two inhalational agents. **Methods:** In this randomised study, patients of age 18–60 years, were allotted to two groups (29, sevoflurane and 28, isoflurane) and received protocol-based anaesthesia. Intraoperatively, different haemodynamic and other data were recorded. **Results:** All mean of averages of individual subject's vitals were comparable between the groups [$P = 0.681, 0.325, 0.803, \text{ and } 0.051$, respectively for systolic blood pressure (SBP), diastolic blood pressure (DBP), mean blood pressure (MBP) and heart rate (HR)]. Higher mean HR was recorded for maximum readings of isoflurane ($P = 0.028$). Equivalency was observed for SBP, MBP, and DBP ($P = 0.000, 0.002, \text{ and } 0.027$, respectively). Process capability indices indicated that sevoflurane had better values (Pp: 0.55 versus 0.41, Ppk: 0.35 versus 0.22) for SBP as with MBP (Pp: 0.62 versus 0.51, Ppk: 0.36 versus 0.33). For achieving optimal vision, higher pump pressures (PPs) were demanded by surgeon ($P = 0.025$) and higher differences observed between initial and highest PPs ($P = 0.027$), in isoflurane subjects. Multivariable analysis revealed that no continuous predictor was able to predict the quality of vision except additional pump flow factor, for both groups. **Conclusion:** Both inhalational agents demonstrated equivalent haemodynamic effects. Increased arthroscopic PP requirements were observed with isoflurane anaesthesia. Sevoflurane may be superior to isoflurane during BCP arthroscopy.

Key words: Arthroscopy, block, brachial plexus, general anaesthesia, hemodynamic, inhalation anaesthesia, surgery

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INTRODUCTION

Shoulder arthroscopic surgery is often performed in beach chair position (BCP). The effects of several anaesthetic techniques and agents for the procedure have been extensively studied.^[1,2] Haemodynamic effects induced by BCP in anaesthetised patients are well-known.^[3] Different inhalational agents at equivalent minimal alveolar concentration (MAC) dosages may exhibit dissimilar haemodynamic effects

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especially in patients with a prior interscalene plexus blockade (ISSB). While these observations could be accounted for by their established mechanisms of action, an unfamiliar yet plausible explanation could be the local anaesthetic-inhalational agent interaction.^[4,5] Previous studies have shown that both sevoflurane and isoflurane reduce mean arterial blood pressure (MBP) to an equivalent magnitude but under different circumstances.^[6,7]

Haemodynamic parameters are of prime importance in arthroscopic surgery due to their direct relationship with arthroscopic pump pressures (PPs), intra-articular bleed, and clarity of vision.^[8] An agent which is capable of preserving autoregulation of cerebral blood flow would be the anaesthetic of choice.^[9] Considering the comparability of isoflurane with sevoflurane at equal MAC, we investigated the hypothesis that both agents produce equivalent haemodynamic effects. Simultaneously, we investigated whether either drug has any additional advantage over the other using secondary outcome measures.

METHODS

This prospective, randomised, parallel design study protocol was approved by the University's Institutional Ethical Committee. The trial was registered prior to patient enrolment at Clinical Trials of Registry of India (<http://ctri.nic.in>, CTRI/2016/04/006830). All patients gave informed consent. Randomly assigned (random number generator, Random#generator, application, Jess

Tucker, version 1.1.3, 2013, Webberface, LLC, iOS application, Category: Utilities, info@webberface.com) patients belonging to American Society of Anesthesiologists (ASA) status I and II, 18–60 years of age, who underwent shoulder arthroscopic surgery over 16-month period (April 2016–August 2017) were enrolled [Figure 1]. Exclusion criteria included allergy to local anaesthetics, preexisting cerebrovascular disease, history of orthostatic hypotension, body mass index of 36 kg/m² or more, impaired kidney function, and coagulopathy. Since an effective preliminary interscalene block formed an essential part of the anaesthetic procedure, patients in whom the regional block was not performed were excluded from the study [Figure 1].

After preoperative assessment and recording of baseline vitals, patients were premedicated with oral ranitidine 150 mg, having fasted overnight before the surgical procedure. No sedatives or opioids were used for premedication.

In the operating room, patients were administered supplemental oxygen while they received intravenous (IV) fentanyl 1–2 µg/kg. Following local infiltration of the skin with 2%, 1 mL lignocaine, ultrasound-guided (SonoSite, M-turbo® system, SonoSite Inc., high frequency, linear 13-6 MHz transducer) interscalene, in-plane block was performed with mixture of 6 mL lignocaine 2% and 20 mL levobupivacaine 0.25% using 23-gauge blunt-bevel needle. The effectiveness of the block was confirmed by absence of sensations over C₅–C₇,

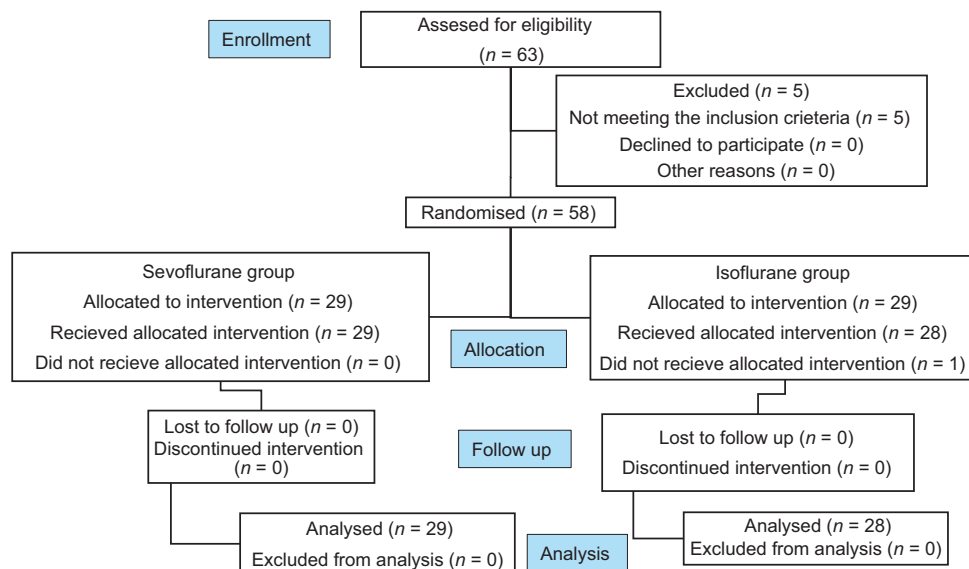


Figure 1: CONSORT flowchart study inclusion criteria

dermatomal distribution and/or free and painless abduction (passive) in patients with painful shoulders. This abolition of touch sensation was tested approximately 15 min later.

After measurements of the preinduction vitals and preoxygenation, anaesthesia was induced with IV propofol 2–2.8 mg/kg. Tracheal intubation was facilitated using IV vecuronium or rocuronium in 2*ED₉₅ doses or succinylcholine 1.5 mg/kg and ventilation was instituted to achieve normocarbica. Five lead electrocardiogram, pulse oximetry, noninvasive blood pressure (in nonoperative upper arm), end-tidal carbon dioxide, and inhalational agent monitoring (Airway Gas Analyser, MDL 94267 OPT-L19; Spacelabs Healthcare, Inc. Snoqualmie, WA, USA) were done during the entire procedure.

Achieving BCP was done over approximately 10–15 min after induction of general anaesthesia. The head was secured in a neutral position. The back of operating table was then raised to 75°–85° above the horizontal plane. With the knees and hips in flexed positions, and the patients' feet resting on protective paddings, care was taken for positioning of arms and neck. Anaesthesia was maintained using either sevoflurane (Datum Vaporizer, MEDITEC England, Abbot Ltd) or isoflurane (Abbott loan vaporiser; Abbott Australia Pty. Ltd) at 1.2–1.5 iso-MAC dosages. Oxygen 33% and nitrous oxide (N₂O) 67% mixture was used in both the groups. Age-related iso-MAC^[10] inhalational concentrations (ChronoMAC, Application Timeline, version 1.0: 2011) were used to achieve the desired end-tidal concentrations for maintenance. Vecuronium- or rocuronium-induced neuromuscular blockade was carefully controlled by train of four (TOF) monitoring. Systolic blood pressure (SBP), diastolic blood pressure (DBP), MBP, and heart rate (HR) were recorded every third minute.

Standard protocol for maintenance of anaesthesia was followed. The minimum difference between the SBP and PP to begin the arthroscopy was 49 mmHg.^[8] End-tidal inhalational agent concentration was adjusted to achieve 1.2–1.5 iso-MAC values for the respective agent during maintenance. Additional opioids and iso-MAC of inhaled agent were adjusted as shown in Supplementary Figure 1. Hypotension was defined as MBP less than 65 mmHg during the surgical period. If two successive readings were less than 65 mmHg, then a vasopressor (ephedrine 3–6 mg, IV) was used. The study interval considered was from insertion of the

arthroscope to its removal. The arthroscopic automated pump (Continuous Wave III Arthroscopy Pump; Arthrex, Arthrex Med. Inst. GmbH, Germany) pressure was 30–40 mmHg and irrigate flow at 30%–40% was to begin with and maintained throughout the procedure. Requirement of increase or decrease in PPs and pump flow, as requested by surgeon, was documented. All patients were administered ondansetron IV, 4 mg, 30 min before the anticipated completion of the surgical procedure. Neuromuscular block was reversed with neostigmine 50–70 µg/kg and glycopyrrolate 10 µg/kg when TOF count of 4 was demonstrated.

The primary outcome variable was 'haemodynamic parameters' which included the recordings of all vitals. We recorded induction to incision time, duration of surgery, initial PPs, highest PP used, initial flow, highest flow used, total saline consumption, difference between highest and initial PPs and flows, average saline consumption/minute, and opioid consumption. The categorical visual analogue scale scores were rated by surgeon (who was blinded for the study) based on vision during arthroscopy as excellent = 4, good = 3, average = 2, and poor = 1. In addition, details of MAC adjustments, additional opioids, hypotension episodes, and vasopressor requirements were noted. All these constituted our secondary outcomes.

Our previous study on shoulder arthroscopy in lateral decubitus position (LDP) demonstrated approximately 10 mmHg mean difference of SBP between group subjects when different techniques and inhalational agents were compared.^[11,12] Based on this, we calculated the sample size for this study. A minimum of 16 patients were required in each group to detect a mean BP difference of 10 mmHg [power 80%, $\alpha = 0.05$, with standard deviation (SD) of 10 in each group] assuming that differences of <10 mmHg would not be clinically significant. However, we included a higher number of subjects since additional statistical methodology using process capability index (PCI) analysis for haemodynamic data evaluation necessitated a minimum number of 25 subjects in each group. *A priori*: compute sample size using two-tailed test (effect size of 1, critical t, 2.006, Df = 52) with 27 patients in each group revealed that the actual power of our study would be 95%. An assumption of 10% dropouts was made.

Statistical analysis was performed using Minitab® 17.1.0., © 2013 Minitab Inc. All data distribution analysis was checked using Shapiro–

Wilk (Ryan–Joiner) test. Data were evaluated using different methods using conventional statistical tests, equivalent tests, PCIs, and multivariable analysis [Supplementary Figure 2]. To test for the differences between study arms, patient characteristics were analysed using independent sample *t* tests for continuous variables or Mann–Whitney *U* test for nonparametric data. Mean (SD) and 95% confidence intervals (CIs) or median (range) were considered. Chi-square test was used to analyse categorical data.

Additional statistical analysis was done using equivalency tests and PCIs. Presuming the hypothesis of equivalency with respect to the haemodynamic effects of sevoflurane and isoflurane in patients undergoing shoulder arthroscopy, we used the two-sample equivalence tests.^[13] This independent conclusion was necessary since statistically proving ‘not being different’ is not as same as ‘equivalent’. A two-sample equivalence test would test two separate null hypotheses in our study. First, the difference between sevoflurane haemodynamics was less than or equal to isoflurane lower limit for equivalence and second, the difference was greater than or equal to upper limit for equivalence. If mean, μ , denoted the average vitals of each group subjects, μ_{sevo} and μ_{iso} were individual averages for sevoflurane and isoflurane, respectively. The two one-sided test procedures required rejecting both of null hypotheses $\mu_{\text{sevo}} - \mu_{\text{iso}} \geq 10$ mmHg and $\mu_{\text{sevo}} - \mu_{\text{iso}} < 10$ mmHg to declare the equivalence. If both null hypotheses were rejected, then the difference would fall within our equivalence interval and we could claim that the means for the vital readings were equivalent.

PCIs^[11,14] were used to evaluate an individual patient’s haemodynamic parameter fluctuations since SDs of individual patients were not assessed during conventional evaluations. We derived PCIs for the desired range of maintained SBP, that is, between 100 and 80 mmHg. These formed the upper specification limit (USL) and lower specification limit (LSL) of systolic pressures (SBP_(100,80)). Similar to SBPs, PCIs for MBPs and PP usage were derived for SLs, separately [SLs for MBP_(80,60), PP_(30,50)]. All PCI data were checked for distribution and data were transformed prior to analysis and derivation of indices. To determine the ability of the inhalational agent to maintain the blood pressure with respect to a predefined range (SL), the PCI, Pp was derived. To analyse whether the fluctuations deviated to higher or lower side of expected limits, the PCI, Ppk was considered.

An ordinal logistic regression analysis was used to find out the associations between visual grading and predictors influencing arthroscopic vision for both agents, separately. Predictors included were age, weight, SBP_{mean}, DBP_{mean}, average saline consumption per minute, additional PPs, and additional flows. All primary and secondary outcomes were compared using a conventional α level of 0.05.

RESULTS

Of 63 patients who underwent shoulder arthroscopic surgeries, 1 patient who refused interscalene block on operative table did not meet the inclusion criteria. Five patients who had a different operating team were excluded prior to randomisation. The remaining 57 were analysed as per protocol.

The groups did not differ by age, sex, weight, and preinduction opioid use. Baseline vitals were comparable. Both groups received similar anaesthetic techniques with respect to regional or general anaesthesia. Surgical details with respect to type of surgical procedures, induction–incision time, surgical duration, initial PPs, and flows were comparable between the groups [Table 1].

The primary independent variable was the SBP and covariables were DBP and MBP. The means of mean SBP, DBP, MBP, and HR recorded (for sevoflurane and isoflurane) were not different between the groups [Table 2]. The comprehensive list of maximum and minimum blood pressure and HR averages is included in Table 2.

While analysing whether sevoflurane was equivalent to isoflurane in achieving haemodynamic status, two-sample equivalency test confirmed that both were equivalent for mean SBP ($P = 0.017$, for limits of 10 mmHg; $P = 0.000$, for limits of 5 mmHg; mean difference of -0.79 , 95% CI of mean difference, -4.01 to 2.44). The equivalency test, $P < 0.05$, allowed the rejection of null hypothesis of ‘difference ≤ -10 mmHg or difference ≥ 10 mmHg’ and accepting an alternative hypothesis of ‘ -10 mmHg $<$ difference < 10 mmHg’. This indicated equivalency between the groups. The test was repeated for limits of 5 mmHg, and rejection of null hypothesis was still possible. Similarly, mean MBPs and DBPs were found equivalent between the groups (limits 5 mmHg, CI: -2.18 to 2.95 , $P = 0.002$ for MBP and limits 5 mmHg, CI: -1.147 to 4.492 , $P = 0.027$ for DBP).

Table 1: Comparison of patient characteristics between the groups

Parameter	Sevoflurane (n=29)	Isoflurane (n=28)	χ^2	95% CI of mean difference	P
Patients data					
Age (years)	48.7 (10.7)	44.3 (14.4)	0.147	-11.2 to 2.3	0.204
Sex male/female	23/6	20/8			0.702
Weight (kg)	65.6 (9.9)	68.3 (12.4)		-8.7 to 3.2	0.361
ASA status					
ASA I, ASA II	17, 12	14, 14	0.15		0.699
Surgical procedure					
Rotator cuff repair	25	19	1.59		0.475
Bankert's repair	2	2			
Others	4	7			
Baseline vitals					
SBP (mmHg)	125.8 (9.8)	123.3 (9.4)		-3.12 to 7.06	0.441
DBP (mmHg)	76.4 (8.3)	77.3 (7.0)		-5.02 to 3.14	0.645
MBP (mmHg)	92.8 (6.8)	92.8 (7.1)		-3.65 to 3.71	0.889
HR (beats/min)	74.1 (10.3)	73.2 (11.7)		-6.75 to 4.95	0.778
Pump characters					
Initial PP (mmHg)	37.2 (4.8)	36.3 (4.8)		0.001-0.000	0.403
Highest PP (mmHg)	45.7 (8.2)	50.4 (9.4)		-9.999 to -0.002	0.025
HP-IP _{diff} (mmHg)	7.6 (8.0)	13.2 (10.6)		-10.58 to -0.67	0.027
Initial PF (%)	35.5 (5.1)	34.6 (5.1)		0.000-0.000	0.519
Highest PF (%)	39.0 (6.2)	42.1 (7.4)		-10.000 to -0.001	0.068
HF-IF _{diff} (%)	3.5 (6.1)	8.8 (10.6)		-10.001 to 0.002	0.069
Anaesthetic and surgical factors					
Induction-incision time (min)	37.4 (8.9)	38.3 (8.9)		-5.63 to 3.82	0.702
Duration of surgery (min)	99.9 (31.9)	94.9 (31.2)		-11.9 to 21.7	0.560
Saline consumption (L)	26.6 (10.3)	28.8 (12.2)		-9.00 to 3.00	0.527
Average saline consumption/minute (mL/min)	2.8 (1.3)	2.6 (1.1)		-0.300 to 0.645	0.338
Bleeding interference with surgery, n (%)	3 (10.4)	6 (21.4)	0.601	-10.49 to 32.17	0.438
Adj. MAC (1.2-1.5), number of patients, n (%)	12 (41.4)	14 (50)	0.149	-19 to 34.93	0.699
Adj. MAC (1.2-1.5), total adjustments, n	22	21			
Adj. MAC (<1.2 or >1.5), number of patients, n (%)	3 (10.4)	4 (14.3)	0.002	-19 to 34.93	0.964
Adj. MAC (<1.2 or >1.5), total adjustments, n	3	4			
Additional intraoperative opioids, number of patients, n (%)	9 (31.0)	12 (42.9)	0.431	-19 to 34.93	0.512
Additional intraoperative opioids, total consumption (μ g)	500	675			
Hypotension (MBP<65 mmHg), number of patients, n (%)	5 (17.2)	7 (25%)	0.158	-15.61 to 30.7	0.691
Hypotension (MBP<65 mmHg) total incidences, n	5	9			
Normotension (baseline achievement), number of patients, n (%)	2 (6.9)	6 (21.4)	1.43	-6.09 to 34.94	0.232
Visual characters: VAS score distribution					
Excellent, good, adequate, poor	14, 11, 4, 0	14, 12, 1, 1	2.83		0.419

ASA – American Society of Anesthesiologists; Adj. MAC – Adjusted minimal alveolar concentration; CI – Confidence intervals of mean difference; DBP – Diastolic blood pressure; HR – Heart rate; HP – Highest pressure; HF – Highest flow; HF-IF_{diff} – Difference between highest and initial pump flow; HP-IP_{diff} – Difference between highest and pump initial pressure; MBP – Mean blood pressure; PF – Pump flow; PP – Pump pressure; SBP – Systolic blood pressure; VAS – Visual analogue scale. Baseline data, anaesthetic and surgical factors, visual grading score distributions were compared between groups. P values are calculated between two groups for sevoflurane and isoflurane (independent sample t-test or Mann-Whitney U-test for continuous data, χ^2 test for categorical data). Values are expressed as mean (SD) or n (%).

In contrast to blood pressures, we observed statistically significant higher HR_{max} averages in isoflurane subjects (CI: -12.4 to -0.7; P = 0.028, independent sample t test). MAC adjustments, opioid usage, and episodes of haemodynamic instabilities were found comparable between the groups. However, interestingly

we noticed requirement of higher PPs and higher differences between initial and highest PPs for optimal vision in isoflurane subjects [CI: -9.99 to -0.002; P = 0.025 and CI: -10.58 to -0.67; P = 0.027, respectively, Table 1]. We found no difference between the groups for other pump parameters.

Table 2: Haemodynamic and arthroscopic pump characteristics comparisons

Parameter	Sevoflurane (n=29)	Isoflurane (n=28)	95% CI for mean differences	P
Conventional parameter				
SBP _{mean}	93.6 (5.2)	94.4 (8.8)	-4.6 to 3.0	0.681
DBP _{mean}	64.2 (6.2)	62.6 (6.5)	-1.7 to 5.1	0.325
MBP _{mean}	74.2 (5.1)	73.8 (6.4)	-2.7 to 3.4	0.803
HR _{mean}	64.7 (7.5)	69.4 (10.2)	-9.5 to 0.02	0.051
SBP _{max}	106.5 (10.1)	110.8 (17.4)	-11.8 to 3.2	0.259
DBP _{max}	74.7 (9.1)	75.8 (12.7)	-6.9 to 4.8	0.726
MBP _{max}	84.5 (8.7)	87.6 (12.7)	-8.9 to 2.6	0.271
HR _{max}	73.2 (9.4)	79.8 (12.4)	-12.4 to -0.7	0.028
SBP _{min}	83.0 (7.5)	81.8 (8.7)	-3.0 to 5.6	0.552
DBP _{min}	53.6 (11.7)	52.5 (7.6)	-4.2 to 6.3	0.689
MBP _{min}	64.6 (7.3)	62.9 (7.1)	-2.2 to 5.4	0.396
HR _{min}	57.7 (7.6)	59.4 (10.7)	-6.6 to 3.2	0.498
PCI BP parameter (For SBP, MBP)				
Pp _{SBP(80, 100)} , Ppk _{SBP(80, 100)}	0.55, 0.35	0.41, 0.22		
Pp _{MBP(60, 80)} , Ppk _{MBP(60, 80)}	0.62, 0.36	0.51, 0.33		
<LSL _{SBP} (%), >USL _{SBP} (%)	3.02, 19.35	3.34, 25.03		
Percentage total _{SBP} outside SLs	22.37	28.36		
<LSL _{MBP} (%), >USL _{MBP} (%)	1.25, 19.77	1.56, 17.46		
Percentage total _{MBP} outside SLs	21.02	19.02		
PCI pump parameter (For PPs, Flows)				
Pp _{Pr(40)} , Ppk _{Pr(40)}	0.75, 0.58	0.6, 0.43		
Pp _{Fi(40)} , Ppk _{Fi(40)}	0.73, 0.62	0.59, 0.53		
<LSL _{Pr} (%), >USL _{Pr} (%)	0, 6.2	0, 7.8		
Percentage total _{Pr} (%) outside SLs	6.2	7.8		
<LSL _{Fi} (%), >USL _{Fi} (%)	0, 5.2	0, 5.8		
Percentage total _{Fi} (%) outside SLs	5.2	5.8		

CI – Confidence intervals of mean difference; DBP – Diastolic blood pressure; FI – Pump flow; HR – Heart rate; LSL – Lower specification limit; MBP – Mean blood pressure; _{max} – Mean of maximum blood pressure or heart rate recorded for individual subject; _{mean} – Mean of mean blood pressure or heart rate of individual subject; _{min} – Mean of minimum blood pressure or heart rate recorded for individual subject; PCI – Process capability index; Pp and Ppk – Representation for process capability indices; Pr – Pump pressure; SBP – Systolic blood pressure; SLs – Specification limits; USL – Upper specification limit; BP – Blood pressure. The values are mean and standard deviations with 95% of CIs for mean difference for conventional parameter comparisons, are shown. PCIs are derived for SBP, MBP, pump pressures, and pump flows for respective values are mentioned for comparisons. For the respective PCI data, percentages of subjects outside the SLs too are shown. P values are calculated between two groups for sevoflurane and isoflurane (independent sample t-test or Mann–Whitney U-test for continuous data)

Since the data for PCI analysis were found as non-normal, a best fit three-parameter Weibull was considered based on the goodness-of-fit tests with lowest likelihood ratio test P values. After data transformation, the PCIs were derived for each group. The derived PCIs show subtle differences of Pp and Ppk of SBP and MBP recordings at predefined USLs and LSLs, between the groups [Table 2 and Figures 2, 3]. This suggested that the blood pressure readings of a larger number of isoflurane subjects had fallen above USLs. With respect to PPs, better PCI values suggested a consistent uniform intraoperative use of PPs in sevoflurane subjects.

Logistic regression multivariable analysis revealed no continuous predictor was able to predict the quality of vision except additional pump flow requirement factor for each group [Table 3]. No other differences were noted between the groups with respect to any particular predictor. No perioperative major complications were noted.

DISCUSSION

During the trial, we attempted to study the haemodynamic parameters as they are directly linked to PPs, intra-articular bleeds, and clarity of vision during shoulder arthroscopy. A few previous studies did focus on comparing haemodynamic effects of different anaesthetic agents, but in the LDP.^[11,12] In contrast to previous findings, we observed equivalent SBPs, MBPs, and HR_{mean}s with both agents in BCP arthroscopy. While rejecting the null hypothesis, we also checked whether sevoflurane could achieve haemodynamic status equivalent with isoflurane.

Cardiovascular effects specific to sevoflurane and isoflurane have been described and compared in multiple studies on animals,^[13] human volunteers,^[7] and ASA I patients.^[6] Decrease in arterial pressure for isoflurane and sevoflurane occurs as a consequence of reduction in left ventricular afterload. BCP augments this effect leading to further reductions. Concomitant administration of N₂O

Table 3: Multiple regression model comparisons for two groups

Predictor	Sevoflurane					Isoflurane				
	Coefficient	SE of coefficient	Z	OR (95% CI)	P ^a	Coefficient	SE of coefficient	Z	OR (95% CI)	P ^a
Covariables or continuous predictors										
Age (years)	-0.017	0.042	-0.400	0.98 (0.91-1.07)	0.686	0.017	0.046	0.370	1.02 (0.93-1.11)	0.709
Weight (kg)	0.040	0.045	0.890	1.04 (0.95-1.14)	0.375	0.045	0.047	0.960	1.05 (0.95-1.15)	0.335
Average saline consumption/min (L/min)	-0.313	0.334	-0.940	0.73 (0.38-1.41)	0.348	0.036	0.590	0.060	1.04 (0.33-3.3)	0.951
Additional pump pressure (mmHg)	-0.211	0.074	-2.840	0.81 (0.7-0.94)	0.005	-0.148	0.074	-1.990	0.86 (0.75-1)	0.039
Additional pump flow (%)	0.068	0.079	0.870	1.07 (0.92-1.25)	0.386	-0.089	0.059	-1.510	0.91 (0.81-1.03)	0.131
SBP _{mean} (mmHg)	-0.022	0.106	-0.210	0.98 (0.79-1.2)	0.833	-0.130	0.084	-1.550	0.88 (0.74-1.04)	0.122
DBP _{mean} (mmHg)	0.032	0.101	0.320	1.03 (0.85-1.26)	0.753	-0.045	0.108	-0.410	0.96 (0.77-1.18)	0.68
Log-likelihood = -21.337					0.037	Log-likelihood = -16.423				0.005
Goodness-of-fit tests										
Pearson			0.188		Pearson			0.999		
Deviance			0.726		Deviance			1		
Somers' D			0.68		Somers' D			0.82		

CIs – Confidence intervals; DBP – Diastolic blood pressure; MBP – Mean blood pressure; _{mean} – Mean of blood pressure; OR – Odds ratio; SBP – Systolic blood pressure; SE – Standard error; Z – Z-statistic. Multiple regression model comparisons for two groups with respect to continuous predictors are shown. The value order response events were excellent, good, adequate, and poor for visual rating. The logit link function, the calculated OR, and a 95% CI for the OR were considered to determine whether the association between the response events and the predictors is statistically significant with α of ≤ 0.05 (adjusted P , P /number of predictors in the model). Predictors included were age, weight, SBP_{mean}, DBP_{mean}, average saline consumption per minute, additional pump pressures, and additional flows as continuous predictors. No categorical predictors were used due to either poor model fit or being a parallel continuous predictor. Average saline consumption/min and duration of surgery were highly correlated, $r=0.683$ (for sevoflurane, $P<0.0001$) and $r=0.684$ (for isoflurane, $P<0.0001$). Similarly, SBP_{mean} and MBP_{mean} were highly correlating for both the groups, $r=0.653$ and 0.848 , respectively, $P<0.0001$. Thus, duration of surgery and MBP_{mean} were dropped from the final model. P^a – adjusted P

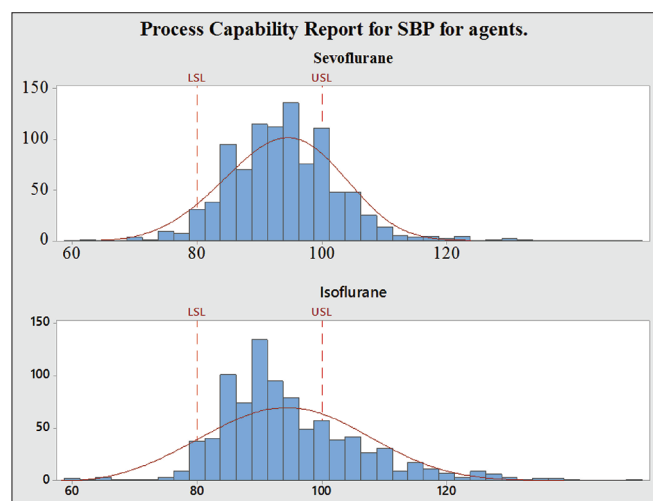


Figure 2: Process capability report for SBPs. Process capability report for SBPs of both groups, for overall processes for SLs (LSL and USL). The assembly fit data PCI values are shown for original (nontransformed) data. Data were transformed prior to derivation of PCIs. X-axis represents the systolic blood pressure readings. LSL (80 mmHg) and USL (100 mmHg) were considered for PCI evaluation. PCI, process capability index; SBP – Systolic blood pressure; LSL – Lower specification limit; USL – Upper specification limit

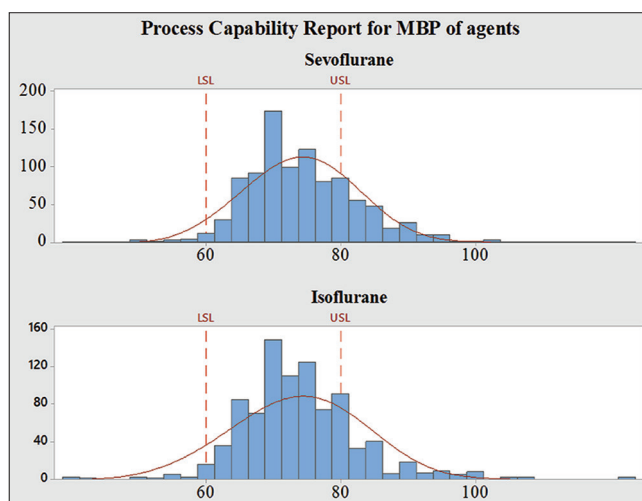


Figure 3: Process capability report for MBPs. Process capability report for MBPs of both groups, for overall processes for SLs (LSL and USL). The assembly fit PCI data values are shown for original (nontransformed) data. Data were transformed prior to derivation of PCIs. X-axis represents the mean blood pressure readings. LSL (60 mmHg) and USL (80 mmHg) were considered for PCI evaluation. MBP – Mean blood pressure; LSL – Lower specification limit; PCI – Process capability index; USL – Upper specification limit

may blunt the hypotensive effects.^[7] Our study groups were comparable since N₂O was used in all along with complete ISBB which created a pain-free status. A dose-dependent hypotensive effect for both the inhalational agents at 1–2 MAC has been established, each however having a

different attributed mechanism of action.^[16] Isoflurane causes increase in HR at 1.5–2 MAC anaesthesia probably in response to simultaneous decrease in arterial pressure, and this was reflected by higher HR_{max} values.^[7] The influence of BCP on HR in the presence of an inhalational

agent may be at variance with that observed with LDP.^[17] Researchers have demonstrated sevoflurane's superiority over isoflurane in preserving baroreceptor reflexes^[18,19] during 1–2 MAC anaesthesia, but this has, however, not been specifically related to BCP.

PCI evaluation demonstrated miniscule difference in the distribution of blood pressure patterns especially with SBP. Overall performance of sevoflurane in preserving SBPs between 80 and 100 mmHg was better. This possibly important clinical difference was not highlighted on conventional statistical analysis.

An interesting observation was the increased number of demands for higher PPs by the surgeon during isoflurane anaesthesia, clearly supported by lower PCI values. With the contingent surgeon's blinding for inhalational agent and blood pressures, the PPs were adjusted based only on visual factor. In the absence of literature evidences supporting this finding, we surmise a few factors that could be responsible for this. First, the surgical and anaesthetic factors listed out in the tables between the groups might collectively lead to higher PP requirements. Second but more important, isoflurane can produce more intense arteriolar dilatations in areas such as bones and joints which are richly vascularised, and this may create a self-perpetuating ooze hampering vision. Corroborative evidence to this effect is provided by a study demonstrating increased microvascular flow index and perfused vessel proportions in the sublingual microcirculation during coronary artery bypass grafting under isoflurane anaesthesia (compared with sevoflurane and desflurane).^[20] Many other studies^[21,22] claim similar effects with increased microcirculatory flows in animal organs though some are contradictory.^[23] Tanaka *et al.*^[24] explained isoflurane's mechanism of vasodilatation through protein kinases. Irrespective of these extrapolations, another factor influencing intraoperative intra-articular bleed could be the underlying pathology to begin with. A real-time *in vivo* laser Doppler study demonstrated higher microvascular blood flow in shoulders with normal rotator cuffs vis-a-vis pathological ones.^[25] Our study had approximately 70% individuals with shoulder pathologies and the numbers were comparable between the groups.

It is uncertain whether the observed difference has resulted in clinically important changes in patient management. Low PPs reduce saline consumption, absorption, and swelling, allow easy surgical handling, and reduce postoperative pain and hospital stay. Model comparisons could identify no factor other than PPs that

influenced visual scores. This is not to be confused with our finding of higher number of demands for increased PP during isoflurane anaesthesia. The final grading of visualisation aimed for is always 3 or higher for any arthroscopy to ensure smooth conduct of the procedure.

Where ischaemic brain damage related to BCP is a concern,^[3] the ability of a specific inhalational agent to prevent this assumes importance. Although no single agent has yet emerged as a superior neuroprotective one,^[26] few studies have shown some differences between sevoflurane and isoflurane. The superiority of sevoflurane over isoflurane in preserving dynamic cerebral autoregulation as measured by transcranial Doppler (TCD) of the middle cerebral artery blood velocity has been demonstrated.^[27] Middle cerebral artery flow velocity when studied through TCD revealed least effects with sevoflurane compared with isoflurane.^[9] The true instances of cerebral desaturation as detected by noninvasive near-infrared spectroscopic cerebral oximetry^[28] had higher margin of safety with sevoflurane-N₂O-based anaesthesia over other techniques.^[29] Relatively lower PP requirements along with the neuroprotection advantage could make sevoflurane the logically preferred inhalational agent.

Our study has its limitations. The haemodynamic effects of MAC may be different for iso-MAC values and will be affected by use of additional opioids. Increased PPs may be demanded by surgeon at regular intervals, but the converse for a 'decreased' demand is less likely. Use of surgical shavers and radiofrequency devices may significantly amend the bleeding. Subjective scorings of visual grade are considered for the entire period, whereas bleeding episodes are sporadic. Bleeding during arthroscopy may depend on underlying shoulder pathology. Secondary outcome analysis may be underpowered. The sample size was a concern when the ordinal logistic regression analysis was used to analyse the visual grading, although the minimum sample size is not yet defined for such an analysis.

CONCLUSION

We conclude that both isoflurane and sevoflurane produced equivalent haemodynamic effects. We observed increased pump requirements with isoflurane anaesthesia. In this context, a future study with a larger sample size may confirm the superiority of one inhalational agent over the other.

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Conflicts of interest

There are no conflicts of interest.

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