Original Article

Effects of ventilation mode type on intra-abdominal pressure and intra-operative blood loss in patients undergoing lumbar spine surgery: A randomised clinical study

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ABSTRACT

Background and Aims: The aim of the study was to evaluate the effect of mode of mechanical ventilation; pressure-controlled ventilation (PCV) vs. volume-controlled ventilation (VCV) on airway pressures, intra-abdominal pressure (IAP) and intra-operative surgical bleeding in patients undergoing lumbar spine surgery. **Methods:** This was a prospective, randomised study that included 50 American Society of Anesthesiologists class I and II patients undergoing lumbar spine surgery who were mechanically ventilated using PCV or VCV mode. The respiratory parameters (peak and plateau pressures) and IAP were measured after anaesthesia induction in supine position, 10 min after the patients were changed from supine to prone position, at the end of the surgery in prone position, and after the patients were changed from prone to supine position. The amount of intraoperative surgical bleeding was measured by objective and subjective methods. **Results:** The primary outcome was the amount of intraoperative surgical bleeding. It was significantly less in the PCV group than in the VCV group (137 ± 24.37 mL vs. 311 ± 66.98 mL) ($P = 0.000$). Similarly, on comparing other parameters like peak inspiratory pressures, plateau pressures and IAP, the patients in PCV group had significantly lower parameters than those in VCV group ($P < 0.05$). No harmful events were recorded. **Conclusion:** In patients undergoing lumbar spine surgery, use of PCV mode decreased intraoperative surgical bleeding, which may be related to lower intraoperative respiratory pressures and IAP.

Key words: Intra-abdominal pressure, pressure-controlled ventilation, prone position, volume-controlled ventilation

INTRODUCTION

Surgical procedures on the spine have witnessed a number of improvements due to better diagnostic modalities and refinements in surgical techniques.[1] Prone position, which is most commonly employed for surgical access results in significant haemodynamic and physiological changes, along with an increase in the intra-abdominal pressure (IAP).[2,3] IAP >12 mm of Hg has been shown to result in various deleterious effects on gastrointestinal physiology, varying from gut microcirculatory hypoperfusion, oedema, mucosal hyperaemia to bowel ischemia. Various direct and indirect methods have been employed so far to measure IAP.[4] Among all the non-invasive methods, measurement of intra-vesical pressure is the most reliable and practical.[5] Pressure-controlled ventilation (PCV) provides the same tidal volume (V_T) with lower peak

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inspiratory pressure (PIP) and a more even distribution of ventilated gas to the whole lung field as compared to volume-controlled ventilation (VCV) mode.[6] Modes of mechanical ventilation by means of their differential effect on intrathoracic pressure can have significant influence on IAP.[7] Raised airway pressures, more so PIP and IAP have been shown to increase the amount of epidural bleeding due to congestion from epidural plexus during surgeries on the spine.[8] However there has been no study which directly correlates the effect of different modes of mechanical ventilation on IAP and surgical bleeding.

We hypothesised that PCV mode would be associated with lower IAP, less surgical bleeding and more stable haemodynamics than VCV mode in patients undergoing lumbar spine surgery. The aim of our study was to study the integrated effects of airway pressures using different ventilatory modes and IAP and consequently surgical bleeding in patients undergoing lumbar surgery in prone position.

METHODS

This prospective, randomised study was conducted on 50 American Society of Anesthesiologists (ASA) class I and II patients between the age of 18–60 years, of either sex posted for elective lumbar spine surgery in prone position, after obtaining written informed consent and approval from institutional ethics committee. The study was registered with Clinical Trial Registry-India (CTRI/2018/03/012673) and was done from January 2017 to March 2018. Patients undergoing emergency spine surgery, prior history of spine or abdominal surgery, contra-indications for bladder catheterisation, uncontrolled diabetes or hypertension, acute or chronic renal failure, ischaemic heart disease, liver disease, respiratory illness, preoperative dysrhythmias, bleeding tendencies or those receiving antiplatelets or anticoagulants, pregnant patients and morbidly obese were excluded from the study.

A thorough pre-anaesthetic check-up was conducted and relevant investigations done prior to surgery. Patients were kept nil orally from the midnight and were premedicated with 0.5 mg alprazolam orally at night and at 6:00 am on the day of surgery. After arrival of the patient in the operation theatre, intravenous fluids were started, standard ASA monitoring was initiated and baseline parameters noted. Anaesthesia was induced by fentanyl (2 μg.kg^{-1}) and propofol (2 mg.kg^{-1}) and oro-tracheal intubation with appropriately sized flexometallic tube was facilitated using atracurium besylate (0.5 mg.kg^{-1}). Patients were catheterised by a transurethral catheter after anaesthesia induction.

All patients were mechanically ventilated using Drager Fabius plus ventilator. In both the groups the total fresh gas flow rate of 2 L/min with oxygen: nitrous oxide (N_2O) in a ratio of 1:1 and no external positive end expiratory pressure (PEEP) was applied. Respiratory rate (RR) was set at 12–14/minute with inspiratory: expiratory ratio at 1:2 to maintain end tidal carbon dioxide ($EtCO_2$) of 36–40 mm Hg. The mode of mechanical ventilation (group allotment) was determined by randomisation using computer generated random numbers.

Group A – Patients were ventilated using VCV mode with tidal V_T of 8 mL/kg ideal body weight and those needing a higher V_T were excluded from the study.

Group B – Patients were ventilated using PCV mode, at peak inspiratory flow of 30 L/min, PIP was initially set at 18 cm of H_2O and adjusted upwards or downwards so that a V_T of 8 mL/kg ideal body weight was achieved [Figure 1]. Patients needing PIP of <10 cm of H_2O or >25 cm of H_2O were excluded from the study.

Anaesthesia was maintained using O_2 in N_2O (1:1) and isoflurane (0.6-3%) on closed circuit using total fresh gas flow of 2 L/min. Inspired concentration of isoflurane was guided by bi-spectral index (BIS) monitoring, maintaining BIS between 40-60. Inj atracurium in increments of 5 mg was administered

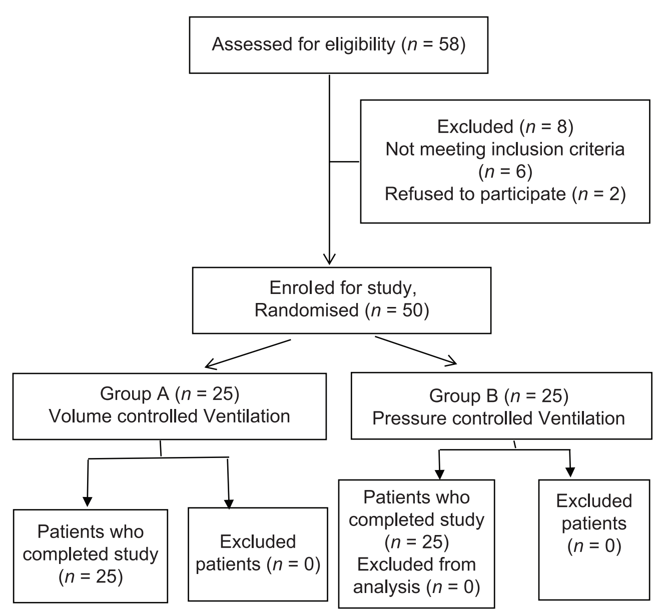

Figure 1: CONSORT diagram

as guided by neuro-muscular monitoring, maintaining a train of four (TOF) count of 0. Patients were shifted from supine to prone position on horizontal cylindrical bolsters ensuring good lumbar spine flexion and avoiding abdominal compression. Haemodynamic parameters including heart rate, non-invasive systolic, diastolic and mean blood pressure (SBP, DBP, MAP) and SpO_2 were recorded at an interval of 5 minutes during the course of surgery till extubation. IAP, peak and plateau airway pressures were measured and recorded after induction of anaesthesia in supine position (T0), ten minutes after shifting the patient in prone position (T1), at the end of the surgery in prone position (T2) and after extubation in supine position (T3). The technique used to measure IAP was based on the procedure as described by Kron *et al*.[9] The measurement was performed by injecting 50 mL 0.9% sterile saline in the empty bladder through the indwelling Foley's catheter. The sterile tubing of the urinary drainage bag was connected to the catheter so as to let the fluid from the bladder fill the catheter tubing to eliminate air from the drainage catheter. The tubing was cross clamped just after the connection point. An 18-gauge needle was then inserted through the catheter sampling port and connected to a pressure transducer, whereas the pubic symphysis was used as the reference point [Figure 2]. The bladder was continuously emptied in between the measurements. The mean abdominal pressure was measured at the end of the expiratory phase to eliminate the influence of respiratory cycle on IAP. SpO_2 was maintained between 95 and 100% and $EtCO_2$ was kept between 35 and 40 mm Hg. In case SpO_2 decreased from 95%, a rescue strategy of stepwise increase of fraction of inspired oxygen (FiO_2) up to 70% was adopted followed by an application of PEEP of five cm H_2O. These patients were excluded from the study.

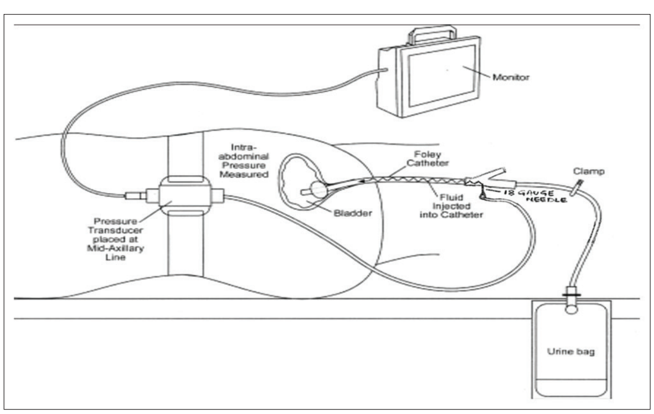

Figure 2: IAP measurement set-up[10]

Intraoperative blood loss was estimated both subjectively and objectively.

Blood loss was measured by noting the difference between the weights of gauze pieces and surgical sponges before and at the end of the surgery. Also, the contents from suction bottle were noted and intraoperative saline used for irrigation was subtracted from this. Blood loss was obtained by summation of these two. For objective assessment the neurosurgeon, first assistant and scrub nurse who were blinded to the group allocation were asked to evaluate intraoperative bleeding by the level of impairment of the visual field by blood as 0 - no impairment, 1 – slightly impaired, 2 – impaired, and 3 – heavily impaired. To minimise the variability of such an evaluation, all cases were operated on by the same neurosurgeon. The patient was returned to supine position after the end of the surgery and trachea was extubated.

A power analysis was conducted using the software package, G*Power version 3.1.9.2 (Franz Faul, university kiel, Germany). The alpha level used for this analysis was $P < 0.05$ and beta was 0.20. By using earlier study done by Koprulu *et al*.[8] as a template and using peak and plateau pressures as parameter, we expected similar results. Power came out to be 1 with effect size of 2.4 with 10% chance of error. The total sample size was calculated to be 50, with 25 patients in each group. Data was described in terms of range, mean ± standard deviation (SD), median, frequencies (number of cases) and relative frequencies (percentages). Comparison of quantitative variables between the study groups was done using Student *t*-test and Mann–Whitney *U* test for independent samples for parametric and non-parametric data, respectively. For comparing categorical data, Chi-square ($\chi 2$) test was performed and exact test was used when the expected frequency was less than 5. A probability value (*P* value) less than 0.05 was considered statistically significant. All statistical calculations were done using computer programs Microsoft Excel version 7 and Statistical Package for Social Sciences (SPSS Inc., Chicago, Illinois) 17 version statistical program for Microsoft Windows.

RESULTS

Both groups were comparable with respect to demographic parameters and ASA status distribution. The platelet count, coagulation profile and duration of surgery showed no significant difference [Table 1].

The baseline and intraoperative trends in HR, SBP, DBP, MAP, SpO_2, and BIS also showed no significant difference in the two groups. The distribution of the type of surgeries done on the lumbar spine was also similar in the two groups [Table 2].

Both peak and plateau airway pressures were significantly higher (p 0.000 and 0.001, respectively) in Group A (18.44 ± 1.58 cm of H_2O and 13.48 ± 2.10 cm of H_2O) than group B (11.62 ± 1.62 and 11.16 ± 2.03 cm of H_2O) in supine position after anaesthesia induction (T0). These findings were also present in prone position: after 10 minutes; T1 (P = 0.000 and 0.038, respectively) and at end of the procedure; T2 (P = 0.000 and 0.039) [Table 3]. The observations for delivered V_T and $EtCO_2$ were not different between the two groups.

Similar was the case with IAP which was higher in group A in supine position (T0); 5.72 ± 1.10 mm Hg as compared to group B, where it was 3.56 ± 1.16 mm Hg (P = 0.0001). The observations for raised IAP were also statistically significant in prone position after 10 minutes; T1 for group A (8.60 ± 1.00 mm Hg) as compared to group B (5.84 ± 1.28 mm Hg) (P = 0.0001). The IAP remained high in prone position at the end of procedure (T2); 8.60 ± 1.19 mm Hg in group A compared to 6.80 ± 1.55 mm Hg in group B (P = 0.0001). However, in supine position after extubation (T3), the difference in IAP (4.12 ± 0.98 mm Hg and 4.04 ± 0.73 mm Hg) was statistically insignificant [Table 4].

By using objective assessment (weight of gauze pieces and volume in suction bottle), blood loss in group A was found to higher as compared to group B, that is, 311 ± 66.98 mL vs. 137 ± 24.37 mL (P = 0.0001) as shown in Figure 3.

Table 1: Demographic data

	Group A		Group B		P
	Mean	SD	Mean	SD	
Age (years)	32.88	10.71	34.84	10.76	0.522
Total Body Weight (kg)	68.16	8.73	68.76	10.03	0.823
BMI (kg/m^2)	23.82	2.27	23.81	2.67	0.992
Gender					
Female	7	28%	9	36%	0.544
Male	18	72%	16	64%	
ASA Grading					
1	20	80%	18	72%	0.508
2	5	20%	7	28%	
PLT count (*10^3.mm^{-3})	276	86.95	245.36	64.45	0.163
PT (seconds)	12.19	1.56	11.85	1.01	0.366
INR	1.08	0.13	1.02	0.06	0.066
Duration of Surgery (minutes)	172.8	53.05	183.8	50.65	0.457

ASA - American Society of Anesthesiologists; PLT - Platelet; BMI - Body mass index; PT - Prothrombin time; INR - International normalised ratio

The degree of bleeding as defined by the level of impairment of visual field (subjective) on a scale of 0 to 3 by the surgeon, first assistant and scrub nurse was also higher in group A as compared to group B [Table 5].

DISCUSSION

Our results show that in patients undergoing lumbar spine surgery, the airway pressures, IAP and the amount of surgical bleeding were less in the PCV group compared to those in the VCV group.

In patients undergoing laparoscopic surgeries, open heart surgery, pelvic robotic surgery, abdominoplasty, radical resection of pulmonary carcinoma; peak, mean and plateau airway pressures were shown to be higher in VCV mode compared to those on PCV mode.[11-15] Similar results were found by Jo *et al.* where PCV provided significantly lower PIP than VCV when the ventilator was set to deliver the same V_T in patients undergoing posterior lumbar spine surgery in both supine and prone positions.[16] Airway pressures have been accepted universally as a method to record respiratory mechanics.[17] We observed that peak and plateau pressures, when recorded in supine position after anaesthesia induction (T0), in prone position after ten minutes (T1) and at the end of surgery (T2) were more in patients ventilated with VCV (group A) as compared to those on PCV (group B) and the difference was statistically significant ($P < 0.05$). The decrease in PIP, associated with PCV is likely to be due to a decelerating inspiratory flow pattern, with the maximum value reaching early in inspiration. The anaesthesiologist managing the case ensured that all patients in both the groups received V_T of 8 mL/kg. Although this was easier to do in VCV

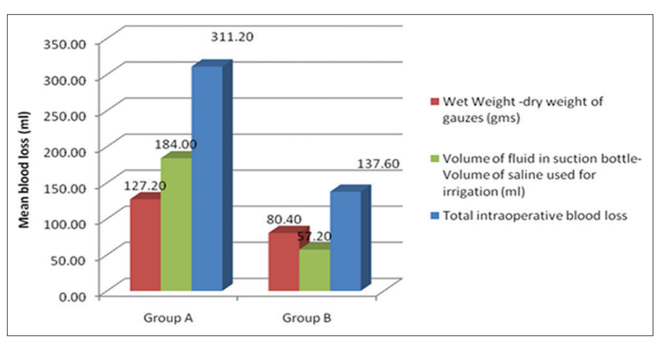

Figure 3: Comparison of blood loss (objective assessment) amongst both groups

Table 2: Distribution of type of surgery

	Group A	Group B	Total	Chi-square value	*P*
Prolapse intervertebral disc (Microdiscectomy)	19	20	39	0.116	0.732
Primary tumour/metastatic malignancy (Tumour resection)	3	2	5	0.222	0.637
Vertebral fracture (Fixation of spine)	2	3	5	0.222	0.637
Tubercular spine (Decompression and fusion)	1	0	1	1.020	0.312
Total	25	25	50		

Table 3: Comparison of respiratory mechanics amongst both groups in different positions

	Group A		Group B		*Z*	*P*
	Mean	SD	Mean	SD		
Peak airway pressure (cm of H_2O)						
Supine position (After induction of anaesthesia) T0	18.44	1.58	11.62	1.62	-15.069	0.000
Prone position (After 10 minutes) T1	23.68	4.21	19.28	2.72	-4.389	0.000
Prone position (end of procedure) T2	23.28	3.97	18.12	2.48	-5.512	0.000
Plateau pressure (cm of H_2O)						
Supine position (After induction of anaesthesia) T0	13.48	2.10	11.16	2.03	-3.420	0.001
Prone position (After 10 minutes) T1	20.32	3.86	18.88	2.64	-1.667	0.038
Prone position (end of procedure) T2	21.32	2.32	17.64	2.64	-0.440	0.039
Delivered tidal volume (mL)						
Supine position (After induction of anaesthesia) T0	477.20	39.53	480.96	39.35	-0.157	0.875
Prone position (After 10 minutes) T1	471.60	36.02	468.40	48.54	-0.597	0.550
Prone position (end of procedure) T2	469.80	34.47	470.80	48.38	-0.050	0.960

Table 4: Comparison of intra-abdominal pressure amongst both the groups in different positions

IAP	Group A		Group B		*Z*	*P*
	Mean	SD	Mean	SD		
Supine position (After induction of anaesthesia) T0	5.72	1.10	3.56	1.16	-4.756	0.0001
Prone position (After 10 minutes) T 1	8.60	1.00	5.84	1.28	-4.653	0.0001
Prone position (end of procedure) T 2	8.60	1.19	6.80	1.55	-4.036	0.0001

Table 5:Comparison of blood loss (subjective assessment) amongst both groups

		Group A		Group B		Total	Chi-square value	*P*
Assessment of blood loss (Grades)-by surgeon	0	9	36%	22	88%	31	15.452	0.001
	1	9	36%	3	12%	12		
	2	6	24%	0	0%	6		
	3	1	4%	0	0%	1		
Assessment of blood loss (Grades)-by first assistant	0	2	8%	15	60%	17	21.305	0.001
	1	9	36%	9	36%	18		
	2	10	40%	1	4%	11		
	3	4	16%	0	0%	4		
Assessment of blood loss (Grades)-by scrub nurse	0	0	0%	4	16%	4	33.371	0.000
	1	2	8%	18	72%	20		
	2	11	44%	3	12%	14		
	3	12	48%	0	0%	12		

mode, in PCV mode this was ensured by making adjustments in PIP.

PCV mode has a potential disadvantage wherein, delivered tidal volume can vary in the face of any change in compliance of lung or ventilator circuit. Thus, close monitoring of delivered tidal volume and $EtCO_2$ are highly recommended while ventilating a patient using PCV.[18] In the present study, this was ensured in all the cases.

Prone position itself is a risk factor for increase in airway pressures due to pressure on abdomen and internal organs which push the diaphragm cephalad resulting in an increased intrathoracic pressure and poor compliance. In a study on patients undergoing spine surgery in prone position on Jackson surgical table, a decrease in dynamic compliance of lungs and increase in airway resistance was observed in VCV mode.[19]

A raised intrathoracic pressure in the prone position may cause obstruction of the inferior vena cava (IVC), decrease the venous return to heart and thus increase the risk of haemodynamic instability.[20,21] It may also lead to a decrease in stroke volume but without much change in HR and MAP as they are counter- balanced by an increase in systemic and pulmonary vascular resistance.[4] We too observed no significant difference in MAP and HR between both the groups at any interval of time which is in accordance with previous studies done in patients undergoing laparoscopic procedures and spine surgeries in supine and prone positions, respectively.[9,22-24]

The modes of mechanical ventilation along with prone position by means of their differential effect on intrathoracic pressure can lead to increased IAP. We studied IAP as reflected by bladder pressure at four time points in different patient positions. Higher IAP was recorded in patients being ventilated using VCV mode as compared to PCV mode when measured in supine position (after anaesthesia induction: T0), in prone position (after ten minutes: T1 and at the end of surgery: T2) and the results were statistically significant ($P < 0.05$). Mechanical ventilation was found to be an independent and predicting factor for development of IAH in critically ill patients.[25] Another study found close positive correlation between V_T, value of PEEP and IAP. Raised IAP is also related to BMI.[6] Therefore, we did not include morbidly obese patients in our study. We also observed that patients on VCV mode had increase in IAP along with raised peak and plateau airway pressures. However, the IAP in supine position after extubation was comparable in both the groups ($P > 0.05$).

Increase in IAP results in a rise in the IVC pressure which is transmitted to the valveless, thin-walled epidural vessels thus causing visual impairment of the surgical field.[26] Koprulu *et al.* in a study on patients posted for microdiscectomy found that the patients ventilated with large V_T had higher incidence of bleeding as compared to those who were ventilated using lower V_T.[9] Han *et al.* also noted a direct relationship between IAP and intraoperative blood loss.[27] The lower intra-operative bleeding in our study could be attributed to lower IAP and lesser peak and plateau pressures because the other hemodynamic and respiratory variables (delivered V_T and $EtCO_2$), were not different between the two groups. In a study by Park *et al*. significantly less bleeding and lower IAP was found in patients placed on a wide width pad support of Wilson frame compared to a narrow one.[28]

Blood loss may vary according to the extent of surgery with maximum losses assumed to be around 10 ± 30 mL/kg.[29] There was a similar distribution of the type of surgeries being conducted in both the groups. We observed lesser blood loss in patients who were ventilated using PCV mode (137.60 ± 24.37 mL) compared to those on VCV mode (311.20 ± 66.9 mL). Although the total amount of blood loss was less, it was significantly different among the two groups. There was lesser obscuration of the surgical field as per subjective assessment by surgeon, first assistant and scrub nurse ($P = 0.0001$).

Observations from previous studies show that patients undergoing posterior lumbar interbody fusion surgery[23] and one-level lumbar discectomy[30] had less surgical bleeding when ventilated using PCV mode. Peak and plateau pressures can be used as an indicator of inappropriate positioning and also used for prediction of the epidural bleeding.[9] A higher PIP, as seen in VCV mode could worsen IVC compression and spinal venous engorgement. When external pressure due to surgical manipulation is applied, PIP in the VCV mode would be higher; therefore, the effects on IVC compression and spinal venous engorgement is greater.[23] Koh *et al.* reported a direct correlation between increased airway pressure caused by change in patient's position from supine to prone and intraoperative surgical blood loss.[31] Malhotra *et al.* compared airway pressure, IAP and blood loss during spine surgery in prone position using three different positioning systems (Wilson frame; spine table; and MaquetThermomodulated pad system) and observed less bleeding in group with lower mean airway pressures and lesser IAP.[32] These findings are in accordance with our study.

One of the limitations of our study was that the observer was not blinded to the group allocation. However, we used a standardised anaesthetic regime and anaesthetic factors which affect surgical bleeding is limited in patients with normal coagulation profiles. Additionally, the surgeon was blinded to the patients' group allocation. Also, continuous measurement of the airway pressures and IAP was not done. This could have helped in correlating exact time points of bleeding with changes in the pressures. However, this was not done as it would warrant the need of interrupting the surgical procedure.

CONCLUSION

Our results show that the patients in PCV group had a significantly less amount of intra-operative blood loss along with lower airway pressures and IAP. Hence, we conclude that PCV can be successfully used as preferential mode of ventilation over VCV in patients undergoing lumbar spine surgery with the advantages of better respiratory mechanics, lower IAP and lesser amount of bleeding thus ensuring better visualisation of surgical field without any adverse effect.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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