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Sidestream Capnographic Monitoring Reduces the Incidence of Arterial Oxygen Desaturation During Propofol Ambulatory Anesthesia for Surgical Abortion

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Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
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Background: This study investigated whether early intervention based on additional use of sidestream capnography could reduce the incidence of oxygen desaturation and hypoxic events in patients receiving propofol anesthesia during surgical abortion.

Material/Methods: We recruited 704 ASAI-III female patients, 18–52 years old and scheduled for planned painless surgical abortion, and randomized them into a control group (n=359) receiving standard monitoring and an experimental group (n=341) receiving standard monitoring and additional capnography. Exclusion criteria were preexisting cardiovascular disease, preexisting hypotension, bradycardia or arrhythmia, and drug allergy. Anesthesia was induced in all patients with propofol using target-controlled infusion at a target propofol plasma concentration of 4 μg/ml. All patients received flurbiprofen axetil 50 mg and 0.5 μg/kg fentanyl 5 min before anesthesia. Bispectral index was used and maintained between 45 and 60. Main outcome measures were apnea or abnormal ventilation status, rate of oxygen desaturation, occurrence of hypoxia and severe hypoxia, and perioperative side effects.

Results: The experimental group had significantly higher rate of apnea or abnormal ventilation, significantly lower rate of oxygen desaturation, and significant lower occurrence of hypoxia and severe hypoxia compared to the control group. We found no statistically significant differences between the 2 groups in the rates of increased oxygen supplementation, assisted ventilation, bradycardia, hypotension, dosage of atropine, dosage of ephedrine or phenylephrine, and the amount of propofol consumed.

Conclusions: Sidestream capnographic monitoring improves early detection of alterations in ventilation parameters and reduces the incidence of oxygen desaturation and hypoxemia resulting from propofol anesthesia during surgical abortion.

MeSH Keywords: Ambulatory Care Facilities • Anesthesia Department, Hospital • Capnography • Propofol

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Background

Surgical abortion is one of the most common medical interventions. Approximately 1.2 million abortions were performed in the United States in 2008 [1]. The number of abortions is increasing in China due to unintended or unhealthy pregnancies [2]. Severe pain can arise from surgical abortion [3]. The use of moderate sedation can improve the acceptance and comfort of the surgical abortion procedure [4]. However, patients under moderate sedation have the potential to progress into deeper sedation and subsequently suffer from drug-associated adverse effects, such as airway obstruction, aspiration, hypoventilation, and hemodynamic instability [5]. Propofol is a short-acting hypnotic agent and is widely used during surgical abortion as a moderate sedative due to its superior pharmacokinetic properties [6,7]. However, the incidence of oxygen desaturation and hypoxic events has not been evaluated in patients receiving propofol during surgical abortion.

Standard patient monitoring during surgical abortion under propofol anesthesia includes pulse oximetry (SaO_2), blood pressure measurements, and electrocardiographic monitoring. However, normal oxygen saturation (SaO_2) may not accurately reflect adequate ventilation. Significant alveolar hypoventilation can be observed even when pulse oximetry shows normal SaO_2. Actually, it is often difficult to detect early hypoventilation, apnea, and hypercarbia with clinical observation and pulse oximetry alone [8]. However, prevention or early detection of these adverse effects is of the utmost importance for patient safety and health. Aside from standard patient monitoring, there is currently no other more effective way to monitor patients receiving propofol anesthesia during surgical abortion.

Carbon dioxide (CO_2) is a metabolic byproduct generated in the body. It dissolves in the blood and is transported in the bloodstream until it reaches the lungs, where it diffuses into the alveoli. Therefore, the exhaled CO_2 can reflect the metabolic, circulatory, and respiratory activity of patients [9–11]. Moreover, measurement of exhaled CO_2 can reflect respiratory ventilation [12]. Currently, analysis of exhaled CO_2 has been clinically used during anaesthesia to detect early adverse respiratory events, in emergency medical services to provide early warning of patient respiratory status, and even in the diagnosis of lung diseases [5,13,14]. Capnography is a quantitative numerical reading of CO_2 levels, and graphically displays CO_2 levels plotted against time. Capnography has been demonstrated to be effective in noninvasively measuring the partial pressure of exhaled CO_2 gas. The partial pressure of exhaled CO_2 is widely thought to be closely correlated with the partial pressure of arterial CO_2 in patients [15,16]. However, no current study has reported the application of capnography in patients undergoing surgical abortion with propofol sedation.

We conducted a randomized, controlled study to evaluate the benefits of real-time capnography in reducing the incidence of oxygen desaturation and hypoxemia in 704 patients receiving propofol during surgical abortion.

Material and Methods

Selection of participants

The inclusion criteria for this study were: 1) female patients above 18 years of age; and 2) patients able to give written informed consent. The exclusion criteria were: 1) patients with preexisting cardiovascular disease, preexisting hypotension (systolic blood pressure below 90 mmHg), bradycardia (heart rate below 50 beats per min) or arrhythmia; 2) patients with a history of allergy to propofol or fentanyl (or other components of its formulation); and 3) the patient physical status classification was IV or V according to the American Society of Anesthesiologists (ASA) Physical Status classification system. A total of 793 patients scheduled for outpatient surgical abortion were enrolled in this study, but only 704 were eligible for randomization and analysis, and 89 cases were excluded from the study. Among the 89 cases, 35 refused to participate, 34 had preexisting bradycardia, 8 had severe heart diseases, and 12 were allergic to propofol (Figure 1).

Study design

This was a randomized, controlled clinical study conducted from November 2010 to May 2013 in a tertiary hospital in China. This study protocol was approved by the Institutional Review Board and Ethics Review Committee of the First Affiliated Hospital of Zhejiang University. Written informed consent was obtained from all patients before the study. Patients were first screened for eligibility. They were then recruited and randomized according to a computer-generated allocation schedule. The subjects were randomly assigned to a control group and an experimental group. Patients in the control group received standard monitoring and capnography but the capnographic data was hidden by an opaque cover. Patients in the experimental group received standard monitoring and a readable capnography. The standard monitoring included clinical observation, pulse oximetry, automated blood pressure monitoring, and electrocardiogram.

Study procedure

Patient demographic data and perioperative variables were collected. Heart rate, pulse oximetry, and electrocardiogram were continuously recorded for all patients. Noninvasive blood pressure was automatically monitored at 3-min intervals. For the assessment of SaO_2, the integrated pulse oximeter in the

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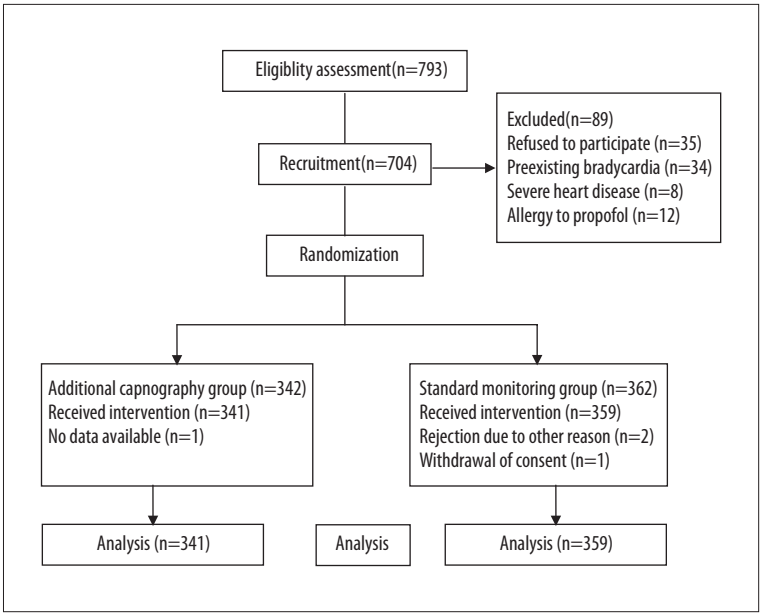

Figure 1. Flow diagram shows enrolled and missed patients.

capnographic device and an additional pulse oximeter were employed for concurrent readings. The facemask combined with integrated sidestream CO_2 sampling and an oral sampling port provided 3.0 L/min of oxygen and continuously sampled CO_2 content of both inspired and expired gas of patients (Smart CapnoLine Plus; Oridion Medical). The sampling line was connected to a portable bedside monitor (Capnostream 20; Oridion Medical) that displayed time-based CO_2 waveform, numerical CO_2 partial pressure (mmHg), derived respiratory rate, and SaO_2 by an integrated pulse oximetry (Nellcor, Covidien, Boulder, CO). During respiration, the capnogram is zeroed as the patient breathes in fresh gas. When the patient starts to exhale, the first breath of gas exhaled will be from the anatomical dead space and will contain little or no CO_2. However, the concentration of CO_2 in the exhaled gas will rise rapidly until it hits a plateau as the alveoli begin to empty. As exhalation proceeds, the concentration of CO_2 remains high and increases slightly. The peak concentration reached at the end of exhalation is the numerical CO_2 partial pressure. As the patient begins to inhale again, the capnogram falls rapidly to zero, indicating the absence of CO_2 in the inspired gas.

Patients in both groups fasted for 6 h and took misoprostol tablets (200 mg, p.o.) 30 min before the operation. Before anesthesia, all patients were given 5 ml/kg Ringer's lactate solution and an experienced gynecologist performed all procedures in the lithotomy position. All patients received 0.5 μg/kg of fentanyl no later than 10 min before the administration of propofol for sedation. Anaesthesia was induced in patients with propofol using target-controlled infusion (TCI) at a target propofol plasma concentration of 4 μg/ml. The surgical period began when the target plasma concentration of TCI propofol reached a stable level of 3.5 μg/ml. If limb twitching was observed and affected the operation, the target propofol plasma concentration was increased to 4.0 μg/ml and reduced to 3.0 μg/ml if apnea occurs in patients for over 10 s. The depth of sedation was monitored using Bispectral index (BIS) and the BIS value was maintained between 45 and 60. An independent anesthesiologist monitored patient respiratory activity. Any signs of apnea, altered ventilation, or oxygen desaturation prompted an intervention that consisted of: (a) verbal or physical stimulation, (b) withholding medication, (c) airway realignment, (d) increasing oxygen supplementation, and (e) the use of airway adjuncts, assisted ventilation, or intubation based on the anesthesiologist's clinical experience. At the completion of surgery, patients were transferred to the recovery room until fully recovered.

Observation

The capnogram waveform enabled visual assessment of ventilation in the experimental group. Here, the capnographic criterion for apnea was the absence of exhaled CO_2. Altered ventilation was defined as a reduction of end-tidal CO_2 of more than half of baseline as shown by the capnogram. The number of oxygen desaturations during anesthesia was recorded. Oxygen desaturation was defined as a 5% or greater decrease in SaO_2 level compared to the baseline value or decrease of SaO_2 level to below 90% [17]. The duration of anesthesia was defined as the time from the start of the first administration of anesthetics until the completion of the operation. The occurrence of apnea, abnormal ventilation, hypoxia (SaO_2 below 90%), and severe hypoxia (SaO_2 below 85%) [18] were closely observed and assessed during the whole period of the study. Additional interventions to combat hypoxia included an increased oxygen supplementation flow above 3.0 L/min

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Table 1. Demographic characteristics of patients.

Parameters	Control group (n=359)	Experimental group (n=341)	P values
Age (years)	36.0±16.0	35.4±15.2	0.746
Body mass index (kg/m^2)	24.5±4.6	25.9±5.2	0.342
Surgical abortion (times)			
1	249 (69.4%)	222 (65.1%)	
2	58 (16.2%)	67 (19.6%)	
3	39 (10.8%)	42 (12.3%)	
>3	13 (3.6%)	10 (2.9%)	
Marital status			
Married	254 (70.8%)	240 (70.4%)	
Single	105 (29.2%)	111 (29.6%)	
ASA classification			
I	202 (56.7%)	189 (55.4%)	
II	107 (29.8%)	112 (32.8%)	
III	50 (13.9%)	40 (11.8%)	
Modified Mallampati score			
1	115 (32.0%)	99 (29.0%)	
2	108 (30.0%)	117 (34.3%)	
3	104 (28.9%)	92 (27.0%)	
4	32 (9.1%)	33 (9.7%)	
Baseline oxygen saturation (%)	98.8±1.6	99.0±1.4	0.056
Baseline heart rate	76.8±14.5	78.1±15.6	0.758
Baseline SBP	115.6±25.0	112.3±28.7	0.893

Student's *t*-test, Fisher's exact test, and Pearson's χ^2 tests were used for statistical comparison between two groups when appropriate. ASA – American Society of Anesthesiologists; SBP – systolic blood pressure.

or assisted ventilation. Adverse hemodynamic responses included bradycardia (heart rate below 50 per min) and hypotension (automated detection of systolic blood pressure below 90 mmHg) resulting from anesthetic administration. In the event of bradycardia, 0.25–0.5 mg of atropine was intravenously injected. In accordance with its response to hypotension, 6–12 mg of the vasoconstrictor ephedrine or 20–40 μg of phenylephrine was injected.

Statistical analysis

SPSS 13.0 software (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Continuous variables are presented as mean ±standard deviation (SD). Categorical variables are shown in number and percent unless indicated otherwise. The *t*-test, Fisher's exact test, and Pearson's χ^2 tests were used for statistical comparison between the 2 groups when appropriate. A $p<0.05$ was considered statistically significant.

Results

Comparison of demographic characteristics of patients in two groups

The patient demographic data are shown in Table 1. No significant differences were observed in age, body mass index, operation time, marital status, ASA classification, Modified

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Table 2. Perioperative parameters of patients.

Parameters	Control group (n=359)	Experimental group (n=341)	P values
Oxygen desaturation	195 (54.2%)	129 (37.8%)	<0.001
Apnea/abnormal ventilation	11 (3.0%)	187 (55.1%)	<0.001
Oxygen saturation <90%	70 (19.5%)	42 (12.3%)	0.007
Oxygen saturation ≤85%	28 (8.0%)	11 (3.5%)	0.023
Oxygen supplement	32 (9.0%)	37 (11.0%)	0.214
Assisted ventilation	3 (0.8%)	1 (0.3%)	0.540
Bradycardia	30 (8.3%)	32 (9.5%)	0.511
Hypotension	14 (3.9%)	14 (4.1%)	1.000
Atropine (mg)	0.50±0.25	0.60±0.27	0.945
Ephedrine (mg)	12.0±3.0	13.0±4.5	0.724
Propofol consumption (mg)	159±103	168±99	0.987
Precedure duration (min)	20±15	22±16	0.962

Student's *t*-test, Fisher's exact test, and Pearson's χ^2 tests were used for statistical comparison between two groups when appropriate.

Mallampati score, baseline oxygen saturation, baseline heart rate, and baseline systolic blood pressure between the control and experimental groups.

Comparison of perioperative parameters of patients between the 2 groups (Table 2)

A significantly higher rate of apnea or abnormal ventilation was detected in the experimental group (55.1%, 95% CI: 39.4.8–62.3%) compared to the control group (3.0%, 95% CI: 1.1–4.2%) (*P*<0.001). Significantly less incidence of oxygen desaturation was observed in the experimental group (37.8%, 95% CI: 33.8–45.2%) compared to the control group (54.2%, 95% CI: 47.8–58.2%) (*P*<0.001). Significantly less occurrence of hypoxia and severe hypoxia was observed in the experimental group (12.3%, 95% CI: 9.0–15.8% and 19.5%, 95% CI: 15.8–24.2%, respectively) compared to the control group (3.5%, 95% CI: 1.1–4.2% and 8%, 95% CI: 1.1–4.2%, respectively) (p=0.007, p=0.023, respectively). No statistically significant differences were observed in the rates of increased oxygen supplementation, assisted ventilation, bradycardia, and hypotension between the 2 groups. In the experimental group, capnography falsely detected 5 patients with apnea or altered ventilation because of the displacement of supplemental oxygen pipeline without other specific causes. These 5 patients had normal respiratory status. There were no significant differences in the dosage of atropine, ephedrine, or phenylephrine, and amount of propofol consumption between the 2 groups. The use of capnography showed no beneficial effect on surgical procedure times.

Discussion

Propofol is widely used for outpatient sedation and inpatient general anesthesia and is a common sedative used in patients undergoing surgical abortion. However, propofol can lead to various adverse effects in patients during anesthesia or sedation. The patients are given interventions based on clinical observation and standard monitoring of the patients' SaO_2, blood pressure, and electrocardiograph. However, the standard monitoring cannot accurately detect early hypoventilation. In this study, real-time sidestream capnography was used to measure the exhaled CO_2 level. Results demonstrated that sidestream capnographic monitoring can help detect early alterations of ventilation parameters and subsequently reduce the incidence of oxygen desaturation and hypoxemia during surgical abortion under propofol anesthesia by prompting an intervention.

Procedural anesthesia or sedation improves patient tolerance of pain and increases the acceptance of the surgical procedure. Propofol is a common sedative used during surgical abortion. Although it is a short-acting anesthetic, propofol can still lead to various degrees of respiratory depression and decrease in blood pressure [19]. Patients undergoing surgical abortion are routinely managed by standard monitoring. However, most episodes of respiratory depression remain undetected by visual assessment and pulse oximetry [20]. Capnography has not been incorporated into the standard monitoring of patients receiving propofol during surgical abortion because of

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the requirement of additional monitoring equipment. In this study, we used sidestream capnography, which was integrated into the facemask for CO_2 sampling from the exhaled gas of patients. This instrument can monitor exhaled CO_2 level in real time during the surgical procedure. Results showed that sidestream capnography can detect early alterations of ventilation parameters.

Consistent with results of a previous study [21], we found that capnography is more accurate in detecting early apnea and hypoventilation than routine clinical observation and pulse oximetry. In this study, significantly higher incidence of abnormal ventilation and apnea was observed in patients receiving additional capnographic monitoring compared to patients who only received standard monitoring. This suggests that clinical observation and pulse oximetry are inadequate for the assessment of ventilation parameters [21]. Also, additional capnographic monitoring detected apnea and altered ventilation in 54.2% of patients, but oxygen desaturation was detected in only 37.8% of patients. This divergence was also observed in a previous study [5]. The authors explained that: 1) not all episodes of perturbed ventilation will result in hypoxemia, especially in the presence of supplemental oxygen; and 2) pulse oximetry exclusively measures hemoglobin oxygenation, which does not adequately reflect the real-time ventilation parameters of patients [5]. We speculated that: 1) the sensitivity of pulse oximetry may be a possible factor, and improving the sensitivity of oximetry should reduce the divergence; and 2) the difference in the definition of altered ventilation may also cause the divergence. In this study, altered ventilation was defined as a reduction of end-tidal CO_2 by more than half of baseline as shown in the capnogram. A higher reduction of end-tidal CO_2 will reduce the divergence. Overall, ventilation may be a more accurate index than hypoxia for gauging the real status of propofol-induced early respiratory depression. Although capnography improves detection of early apnea and hypoventilation, an anesthesiologist's clinical observation cannot be totally replaced by capnography. In this study, apnea or altered ventilation was detected in 5 patients by capnography, but these patients exhibited normal respiratory status and were finally identified as false-positive alarms due to technical problems.

The main aim of the current study was to investigate whether early intervention based on the additional information provided by capnographic monitoring could reduce the incidence of oxygen desaturation and hypoxic events during propofol anesthesia for surgical abortion. In this study, significantly less oxygen desaturation and less occurrence of hypoxia were detected in patients observed under additional capnographic monitoring compared to patients observed under standard monitoring alone. The results suggest that early intervention guided by sidestream capnography can reduce the occurrence of propofol-induced adverse effects. These results also demonstrate that detection of early alteration of ventilation parameters can reduce the incidence of oxygen desaturation and hypoxemia, which might be a universal index for patients using propofol as an anesthetic or sedative. However, normal capnogram parameters do not guarantee sufficient oxygenation, and standard monitoring is also indispensible for clinical practice. Therefore, capnography should be considered as a useful adjunct in these patients. In this study, no differences in the full recovery time and propofol consumption were observed between the 2 groups. Accordingly, capnography has no benefit on the economic cost to patients.

Conclusions

Sidestream capnographic monitoring of ventilatory adequacy reduces the incidence of oxygen desaturation and hypoxemia during surgical abortion under propofol anesthesia. The introduction of capnography monitoring confers no beneficial effect on procedural times.

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