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Original Contribution

# Respiratory gas exchange during robotic-assisted laparoscopic radical prostatectomy☆

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**Abstract**

**Study Objective:** Robotic-assisted laparoscopic prostatectomy requires patients to be secured in a steep Trendelenburg position for several hours. Added to the $CO_2$ pneumoperitoneum that is created, this positioning invariably restricts diaphragmatic and chest wall excursion, which can adversely affect respiratory gas exchange. This study sought to measure the extent of respiratory gas change during this procedure.

**Design:** Retrospective, institutional review board approved.

**Setting:** Operating room.

**Patients:** N = 186 males, American Society of Anesthesiologists 2-3, with prostatic carcinoma undergoing robotic-assisted laparoscopic radical prostatectomy.

**Interventions:** Arterial blood gases and noninvasive respiratory measurements were recorded for those patients (n = 32) in whom a radial arterial catheter had been inserted intraoperatively, specifically timed to different phases of the procedure: supine lithotomy, steep Trendelenburg, and return to supine. Ventilatory parameters were standardized.

**Measurements:** Systemic blood pressure, heart rate, respiratory rate, $Pa_{O_2}$, $Pa_{CO_2}$, oxygen saturation as measured by pulse oximetry, and end-tidal carbon dioxide pressure.

**Main Results:** Although no patients developed perioperative respiratory complications, the $Pa_{O_2}$ invariably fell (395 vs 316 mm Hg; $P = .001$) while the patients were in steep Trendelenburg, and the $Pa_{CO_2}$–end-tidal carbon dioxide pressure rose (10.0 vs 13.4 mm Hg; $P < .0001$). Upon return to supine, patients' respiratory measurements promptly returned to within 15% of baseline. Subgroup analysis for high-BMI vs low-BMI patients as well as for patients with pulmonary disease and/or a smoking history showed similar individual effects and only small, although significant, respiratory gas exchange aberrations.

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**Conclusions:** Positioning patients with a $CO_2$ pneumoperitoneum in steep Trendelenburg for several hours imposes restriction of diaphragmatic and chest wall movement sufficient for respiratory gas exchange to be adversely affected. Return of function to within 15% of baseline occurred within minutes after return to supine and release of the $CO_2$ pneumoperitoneum. No patients during the study period developed pulmonary complications that required alteration in their level of care.


## 1. Introduction

Robotic-assisted laparoscopic radical prostatectomy (RALP) is currently the most commonly used surgical technique for treatment of localized prostate cancer. It requires the patient to be positioned on the operating room table with the legs raised in a modified lithotomy position, the thorax tightly restrained with adhesive tape, and the head down 30° from supine in extreme Trendelenburg position. Coupled with the required surgical pneumoperitoneum, this positioning invariably compromises total respiratory compliance. Attempting to maintain adequate minute ventilation without causing barotrauma, the anesthesiologist frequently encounters impaired oxygenation and carbon dioxide elimination during the procedure.

Trendelenburg positioning and $CO_2$ pneumoperitoneum adversely affect oxygenation and increase the alveolar to arterial oxygen gradient by decreasing functional residual capacity and increasing pulmonary shunt fraction. What is less frequently observed is that the reduction in functional residual capacity also adversely affects $CO_2$ elimination and increases the arterial to end-tidal carbon dioxide pressure gradient ($P_{a\text{-}ET}CO_2$) by increasing dead space ventilation [1-3]. Increasing age also contributes to an increase in $P_{a\text{-}ET}CO_2$ [2,4], which is relevant because RALP is typically performed on an aging male population due to the nature of prostate cancer. Although several studies have looked at various parameters including pulmonary blood flow, pulmonary gas exchange, lung compliance, and shunt during different combinations of steep Trendelenburg and $CO_2$ pneumoperitoneum [1,5-7], the extent to which oxygenation and ventilation might be compromised intraoperatively during RALP remains poorly documented. This study sought to further quantify the extent of respiratory gas exchange impairment during this procedure.

## 2. Materials and methods

After approval from the hospital's institutional review board, we reviewed the medical records of all patients at our hospital who had undergone RALP during 2008 and the first 6 months of 2009. All patients (n = 186) who underwent this procedure during the study period were included. All patients had been deemed suitable to undergo general anesthesia for this elective surgery and were classified as American Society of Anesthesiologists I-III.

Upon review of the medical records, we found 32 patients who had radial arterial catheters placed and blood gas data available from multiple key points of the surgical operation including anesthetized baseline (supine lithotomy), after $CO_2$ insufflation with extreme Trendelenburg, and after return to supine. From each of these patients' medical records, we extracted their age, height, weight, and pulmonary status (smoking history, pulmonary function tests, and chronic obstructive pulmonary disease diagnosis) as well as intraoperative tidal volume, respiratory rate, positive end-expiratory pressure (PEEP) level, ratio of inspiratory time to expiratory time ratio, peak airway pressure, pulse oximetry, end-tidal $CO_2$ ($ETCO_2$), $Pa_{O_2}$, $Pa_{CO_2}$, blood pressure, and heart rate.

Our institutional experience with these cases had led us to empirically determine that the optimal ventilation for these patients is achieved with pressure-controlled mechanical ventilation to an intended tidal volume of 6 mL/kg with a ventilator rate of 10 breaths per minute, an I/E ratio of 1:1, and PEEP of 5 cm $H_2O$. We did not allow the peak airway pressure to exceed 40 cm $H_2O$. Consequently, if maintaining a tidal volume of 6 mL/kg under this ventilator pattern caused the peak airway pressure to exceed 40 cm $H_2O$, we would decrease the tidal volume so as to keep the peak airway pressure below this level and incrementally raise the respiratory rate to as high as 13 breaths per minute to approximate a constant minute ventilation. This protocol of mechanical ventilation was indeed used in all 32 of this subgroup of patients. Anesthesia was maintained with sevoflurane or desflurane in 100% oxygen as well as nondepolarizing neuromuscular blockade for all patients; fentanyl was added in 50-μg increments to maintain heart rate in the 60-100 beats per minute range.

Collected data were used to compare changes in pulmonary function during the procedure. Continuous data were analyzed using a 2-tailed Student *t* test. In comparing individual patients throughout different phases of the surgical procedure, we analyzed the data with a paired *t* test. Data obtained from arterial blood gas measurements were also analyzed using analysis of variance to detect differences for the group as a whole among the stages of the surgical procedure. $P < .05$ was considered statistically significant.

We also performed subgroup analyses to determine if there were any differences in respiratory changes between