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Effects of steep Trendelenburg position for robotic-assisted prostatectomies on intra- and extrathoracic airways in patients with or without chronic obstructive pulmonary disease

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Editor's key points

- Prolonged use of the steep Trendelenburg position during surgery can cause upper airway oedema and reduced lung compliance.
- This study found that airway resistance and nasal flow decreased at 2 h after robotic prostatectomy.
- These changes had resolved by 24 h but were more marked in patients who also developed conjunctival oedema.
- In these patients, chemosis after surgery is associated with upper airway oedema.

Background. The use of the steep Trendelenburg position and abdominal CO_2-insufflation during surgery can lead to significant reduction in pulmonary compliance and upper airway oedema. The postoperative time course of these effects and their influence on postoperative lung function is unknown. Therefore, we assessed intra- and extrathoracic airway resistance and nasal air flow in patients with or without chronic obstructive pulmonary disease (COPD) during robotic-assisted prostatectomy.

Methods. In 55 patients without and 20 patients with COPD spirometric measurements and nasal resistance were obtained before operation, 40 and 120 min, and 1 and 5 days after operation. We measured vital capacity (VC), forced expiratory volume in 1 s (FEV1), maximal mid-expiratory and inspiratory flow (MEF50, MIF50), arterial oxygen saturation, and nasal flow. The occurrence of postoperative conjunctival oedema (chemosis) was also assessed.

Results. In patients without COPD, MEF50/MIF50 increased and nasal flow decreased significantly after surgery ($P<0.0001$) and normalized within 24 h. VC and FEV1 decreased after operation with a nadir at 24 h and recovered to normal until the fifth day ($P<0.0001$). In patients with COPD, changes in MEF50/MIF50 and nasal flow were similar, while changes in VC and FEV1 lasted beyond the fifth day ($P<0.0001$).

Conclusions. Robotic-assisted prostatectomy in the steep Trendelenburg position led to an increase in upper airway resistance directly after surgery that normalized within 24 h. The development of chemosis can be indicative of increased upper airway resistance. In patients without COPD, VC and FEV1 were reduced after surgery and recovered within 5 days, while in patients with COPD, the alteration lasted beyond 5 days.

Keywords: airway resistance; head-down tilt; prostatectomy, robotic assisted; pulmonary disease, chronic obstructive; respiratory function tests; surgical procedures, minimal invasive

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Minimal invasive robotic-assisted prostatectomies offer fast recovery, low postoperative pain scores, minimal blood loss, and good functional results.[1–4] Therefore, robotic-assisted prostatectomies have found wide spread acceptance and are already the preferred technique for this type of surgery.[1–4] However, during surgery, this technique requires the steep Trendelenburg position and abdominal gas insufflation. The steep Trendelenburg position for several hours can lead to expression of oedema of the head and neck and reduction in pulmonary compliance,[5–7] and might lead to oedema of the upper airway. In fact, there has already been reported a case of severe dyspnoea because of an upper airway oedema with the need for reintubation of the patient.[8]

In 2006, Chiu and colleagues[9] demonstrated that fluid shifts from the lower body increases pharyngeal resistance in healthy subjects. Increased upper airway resistance compromises inspiration more than expiration and can clinically be diagnosed by inspiratory stridor. For quantification of changes in upper airway resistance, measurements of the ratio of maximal expiratory flow divided by maximal inspiratory flow at 50% of vital capacity (VC) (MEF50/MIF50) have been established.[10] In addition, measurements of nasal flow can give information about the resistance in the upper most part of the airway.

Besides alteration of upper airway resistance, robotic-assisted prostatectomies in the Trendelenburg position can lead to significant reduction in pulmonary compliance.[5–7] Therefore, not only upper airway resistance is affected, but also pulmonary ventilation. Because patients with an already compromised pulmonary function might be even more at risk to suffer from altered lung function, we not only evaluated lung function in patients free of pulmonary disease but also in patients with chronic obstructive pulmonary disease (COPD).[11–13]

Overall, to evaluate the influence of robotic-assisted prostatectomies in the Trendelenburg position, we assessed parameters of intra- and extrathoracic resistance and nasal airflow, directly after surgery and during the following week. Our primary hypothesis was that there was no change in the ratio of MEF50 over MIF50, as a parameter of extrathoracic airway resistance, directly after surgery compared with preoperative baseline.

Methods

Patients

After approval by the local ethics committee (Chamber of Physicians of Nordrhein, Düsseldorf, Germany, Registration-Number 114/2009), 60 patients without COPD and 20 patients with COPD were enrolled in this study. All of the patients with COPD were already diagnosed with COPD before surgery by their internists or pulmonologists. Diagnoses were made according to the GOLD classification.[14] Subsequently, the diagnosis was confirmed by their history of symptoms and their baseline lung function measurements. Based on our baseline lung function measurements, we enrolled three patients with COPD stage I, 14 patients with stage II, and three patients with stage III (Fig. 1).[14]

All patients were undergoing a robotic-assisted prostatectomy and gave their informed written consent to participate in this study. None of the patients had a history of significant cardiac diseases or obstructive sleep apnoea syndrome.

Methods

Lung function measurements were performed with a spirometer (pneumotachograph, VIASIS, Würzburg, Germany). On the day before surgery, in all patients baseline VC, forced expiratory volume in 1 s (FEV1), maximal expiratory flow at 50% of the VC (MEF50), and maximal inspiratory flow at 50% of the VC (MIF50) were assessed in the sitting position. In addition, nasal flow was measured separately for the right and left side at the end of each measurement.[15–17]

With respect to the influence of a change in posture from the sitting to supine position,[18 19] all subsequent measurements were performed in the supine position with the upper body tilted upwards by 40°. According to international guidelines, the best of three measurements was used for analysis.[20]

Protocol

On the morning of surgery, lung function measurements and nasal flow were recorded in the supine position. Before surgery, a peripheral i.v. cannula was sited and standard monitoring (ECG, non-invasive arterial pressure measurement, pulse oximetry) was applied. Twenty-six of the patients without COPD and all of the patients with COPD received a low-thoracic epidural catheter at T9/10 or T10/11 thoracic vertebral interspace. After the placement of the epidural catheter, general anaesthesia was induced with propofol, remifentanil, and mivacurium and maintained with isoflurane and remifentanil. Mechanical ventilation was set to a tidal volume of 6–8 ml kg^{-1} body weight and an end-expiratory pressure of 5–7 cm H_2O according to the attending anaesthetist with the intention to achieve normoventilation (end-expiratory CO_2 of $<$38 mm Hg).

In patients without an epidural catheter, neuromuscular block was maintained with repeated administration of mivacurium. Train of four was controlled at the end of surgery and the patients' trachea was extubated when the train of four showed a recovery to $>$95% from baseline.

Forty minutes after extubation of the trachea, the first lung function and nasal flow measurements were performed in the recovery room and repeated after 120 min, 24 h, and after 5 days. Always at the time of the lung function measurements, pain (Numerical Rating Score, with 0 for no pain and 10 for worst imaginable pain) and the presence of conjunctival oedema (chemosis) were assessed. Chemosis was assessed as clinically present or not. In the case of questionable chemosis formation, it was described as 'no chemosis'. According to the ophthalmological score for chemosis, 'No' would include grades 0 and 1, while 'Yes' would include grades 3 and 4.[21]

Data analysis

Sample size calculation was based on the primary hypothesis that there is no significant difference in the MEF50/MIF50 ratio with a difference to detect of minimal 0.10. Calculations were based on an α-error of 0.05, a β-error of 0.8, and a standard deviation of 0.15. The result was a minimal number of 19 patients. We rounded the number to 20 for the group of patients with COPD and enrolled 60 patients free of pulmonary disease.

In addition, three secondary hypotheses were tested. First, there was no difference in VC within each group when values before and after surgery were compared. Secondly, there was no difference in FEV1 within each group when values before and after surgery were compared. Thirdly, there was no difference in nasal flow within each group when values before and after surgery were compared.

The primary hypothesis was tested by analysis of variance (ANOVA) for repeated measurements followed by a *post hoc* test with the Bonferroni correction for multiple testing. Patients' characteristics were tested by Student's *t*-test. Null hypotheses were rejected and significant differences assumed with $P<0.05$.

In addition, we tested for a statistical difference between patients with or without chemosis with respect to the ratio of MEF50/MIF50 or nasal flow before *vs* directly after surgery. The effects of chemosis on nasal flow and MEF50/MIF50 were tested by repeated-measures ANOVA.

Data are presented as mean and 95% confidence intervals or as box plots as indicated.