



## Review Article

# Anaesthesia concerns of steep Trendelenburg position in robotic pelvic surgeries: A critical review

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## ABSTRACT

Robot-assisted pelvic surgeries in steep Trendelenburg position present unique challenges to the anaesthesia team. Pneumoperitoneum, also, puts additional strain on the cardiovascular and respiratory requirements of the patient. In-depth knowledge of the effect of this position on patient's physiology is essential for intraoperative safety and better management. Robotic arms can also cause steric hindrance and limited access to the patient thus better intraoperative communication may help in averting any untoward event. With this review, we discuss the effect of steep Trendelenburg position and pneumoperitoneum on the intraoperative physiology of the patient.

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## 1. Introduction

Pelvic surgeries have always been exigent for the surgeons due to the limited area of access to relatively important anatomical landmarks. Minimal access surgical techniques such as robot-assisted surgery (RAS) with better ergonomics, stereoscopic view and increased manoeuvring have made access to the pelvic relatively simpler.<sup>1</sup> The spectrum of various robotic surgical procedures which need the steep Trendelenburg position includes; radical prostatectomy, radical cystectomy, ureteric reimplantation, hysterectomies, vesicovaginal repairs and various colorectal surgeries. Historically, Friedrich Trendelenburg, a German pioneer in the field of genitourinary surgery, propounded this position and was subsequently popularized by Walter Cannon in the earlier decade of 20<sup>th</sup> century during the first World War for the treatment of hemorrhagic shock.<sup>2</sup> RAS of the pelvis comes with its unique positional and technical requirements. Firstly, the patient needs to be placed in steep Trendelenburg position with an angle of around 30 to 45 degrees. This positioning allows for an

adequate intra-abdominal workspace and better delineation of crucial anatomic landmarks. Gravity allows bowel loops to be retracted into the concavity of diaphragm leading to better exposure of operative field. The combination of lithotomy position, insufflation pressure and steep head low position induces alterations in physiological working of cerebral, hemodynamic, pulmonary, renal, ocular, and other systems. Such alterations in the physiological homeostasis warrant an in-depth knowledge and awareness of multi-systemic concerns and challenges. Thus with this study, we aim to provide a review of the literature regarding the effects of this steep Trendelenburg position on patient physiology and associated technical nuances during anaesthesia.

## 2. Materials and Methods

In this study, we performed a non-systematic literature search of PubMed to identify relevant articles about the effect of steep Trendelenburg position during minimally invasive robot-assisted pelvic surgeries.

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### 2.1. Equipment and hardware concerns

Special precautions are needed while using the da vinci surgical system in addition to the normal laparoscopic procedures. After docking of the robotic trocars, adequate depth of anaesthesia and proper muscle relaxation is required to avoid any patient movement which may strain port sites and may cause inadvertent injuries to vital vascular or visceral structures inside the patient's body. A contingency plan must be communicated to the surgical team to remove and pull back the trocars and robot from the patient's body in less than a minute if needed.<sup>3</sup> In addition, the bulky equipment causes steric hindrance in accessing the patient if the anesthesiologist needs to. It is judicious to have a second intravenous line in place should the primary intravenous site be inaccessible or dysfunctional. The robot also interferes with access to the patient's airway and chest. The endotracheal tube should be securely taped to the patient, allowing no migration once the tube is situated. The anesthesiologist also needs to remember that insufflation and Trendelenburg position can cause the diaphragm, lungs, and carina to shift cranially, so endobronchial intubation can occur after positioning and the pneumoperitoneum is established.

### 2.2. Effect on the cardiovascular system

Hemodynamic considerations require a constant vigil about the three factors that will affect the cardiopulmonary status of the patient – steep Trendelenburg position, lithotomy position and pneumoperitoneum. In Trendelenburg position, blood from the periphery, especially lower limbs, returns to the central circulation. This increased return to central circulation causes a stretch of baroreceptors situated in the aortic arch and carotid bifurcation.<sup>4</sup> A rise in hydrostatic pressure causes reflex vasodilatation. This increase in venous return is increased by the lithotomy position which leads to decreased oxygen tension and rise in the partial pressure of carbon-di-oxide ( $\text{PaCO}_2$ ). Conflicting results in various studies have been seen with respect to changes in various circulatory parameters including change in heart rate and increase in mean arterial pressure (MAP), central venous pressure (CVP) and cardiac output in robot-assisted radical prostatectomy (RARP) cases. Choi et al. and Lester et al. showed 3 times rise in CVP without a rise in cardiac output and 2 times rise in pulmonary artery pressure and pulmonary capillary wedge pressure (PCWP) with a 35% rise in MAP and 20-25% rise in systemic vascular resistance (SVR).<sup>3</sup> Findings in the study of Falabella et al. also concurred with a 20% rise in MAP and rise in SVR after Trendelenburg position with fall in cardiac output.<sup>5</sup> Pneumoperitoneum, in addition, decreases venous return with lower extremity oedema and an almost 50% reduction in cardiac index especially in steep Trendelenburg position.<sup>6</sup> Those with compromised cardiac function have a

tendency to have increased preload which can subsequently precipitate heart failure.

### 2.3. Effect on the respiratory system

Cephalad displacement of the diaphragm due to steep Trendelenburg position reduces pulmonary compliance. Furthermore, steep Trendelenburg position also has a negative effect on respiratory mechanics, arterial oxygenation and functional residual capacity. Pneumoperitoneum with Trendelenburg position leads to a 50% rise in peak and plateau pressure. This requires elevated peak pressure to keep constant minute volume, thereby increasing risks of barotrauma. In addition, cerebral perfusion pressure (CPP) and oxygenation were well preserved due to a greater increase in MAP than CVP during the Trendelenburg position. Badaway et al. reported an incidence of intraoperative hypercapnia in 18% of their series of 133 patients undergoing robotic hysterectomy. Their incidence of significant intraoperative hypoxemia was less than 4%.<sup>7</sup>

Schrijvers et al showed a rise in dead space ventilation during steep tilt position but the pulmonary gas exchange was well preserved.<sup>8</sup> Kilic et al., in their study compared changes in respiratory parameters among patients with chronic obstructive pulmonary disease (COPD) and non-COPD. They found that resistance of upper airway increased, nasal flow decreased, vital capacity and forced expiratory volume in 1 second (FEV1) decreased and returned to normal in 24 hours in non-COPD patients but it took 5 days to normalise in patients with COPD.<sup>9</sup> Other studies also showed increased complications in patients with COPD with steep Trendelenburg position.<sup>9</sup> Chest banding used to stabilise the patient from falling off the table during tilt is also found to decrease lung compliance.<sup>10</sup> Position of the endotracheal tube (ETT) before and after pneumoperitoneum and placing the patient in steep Trendelenburg position is recommended as there is a possibility of ETT displacement into the bronchus due to distance changes between the vocal cords/ETT tip and the ETT tip/carina.<sup>11</sup> The rate for re-intubation is found close to 0.7%, whereas the rate for delayed extubation lies close to 3.5%.

### 2.4. Effect on the cerebrovascular system

Steep Trendelenburg position as well as pneumoperitoneum both cause rise in intracranial pressure (ICP).  $\text{CO}_2$  insufflation while creating pneumoperitoneum causes decreased blood flow to abdominal organs by mechanical compression and also leads to fall in return from lumbar venous plexus. This further contributes to the rise in ICP. These factors lead to decreased cerebral venous drainage, increased cerebral blood volume and cerebrospinal fluid volume. Cerebral oedema can cause

confusion and decreased consciousness. Park et al noted a rise in cerebral oxygenation during robotic surgeries in patients without intracranial pathology.<sup>12</sup> Cerebral oxygenation rise is secondary to raise cerebral blood flow and pCO<sub>2</sub> levels. In patients undergoing robotic prostatectomies, Kalmar et al reported maintenance of CPP above the lower threshold of autoregulation of cerebral circulation due to a simultaneous increase in MAP and CVP.<sup>13</sup>

### 2.5. Ocular concerns

Steep Trendelenburg position and pneumo-peritoneum cause a rise in intraocular pressure (IOP) secondary to high CVP. Also, ocular perfusion is decreased. Though visual impairment is quite uncommon, it has been reported by Weber et al, as 2 cases of posterior ischaemic optic neuropathy after robot-assisted radical prostatectomy.<sup>14</sup> In a study by Awad et al., it has been found that IOP may rise to a peak of about 13 mm Hg above the pre-induction level at the time of conclusion of surgery.<sup>15</sup> Nishikawa et al. showed that the rise in IOP was attenuated in 25° Trendelenburg position compared to 30° in RARP.<sup>16</sup> Another study showed that a rise in IOP was significantly more in patients in Trendelenburg with prone position compared to flat prone position. Some studies have even shown no change in IOP after the Trendelenburg position.<sup>17</sup>

Corneal abrasions are seen to occur about 6.5 times more after robotic surgeries with Trendelenburg position than open pelvic surgeries.<sup>18</sup> Specifically, the incidence of corneal abrasions in cases of robot-assisted radical prostatectomy ranges from 3 to 13.5%. The cause for corneal abrasions has been attributed partially to raised CVP and partially to sub-optimal eyelid closure during surgery. The corneal desiccation may be secondary to conjunctival oedema leading to separation of the eyelids. This may be prevented by using ophthalmic ointments in such patients.<sup>19,20</sup>

### 2.6. Facial oedema

The increase in capillary hydrostatic pressure causes accumulation of fluid in interstitial space of dependent areas which is most apparent in the form of peri-orbital and conjunctival tissue. It has been found that facial oedema and peri-orbital oedema can be indicative of laryngeal oedema. Steep tilt Trendelenburg position can cause laryngeal oedema and develop respiratory distress or airway compromise. Studies have suggested the need for careful management of the airway during extubation, including delaying extubation until the airway oedema subsides. Leak test can be performed before extubation to rule out laryngeal oedema.

### 2.7. Obese patients

Obesity causes measurable changes in respiratory physiology which includes decreased FRC, lower chest compliance and altered oro-pharyngeal anatomy. Obesity is also linked with comparatively longer operative time and increased complications. Steep Trendelenburg position causes increased upper airway resistance more in obese patients with BMI > 30 kg/m<sup>2</sup> compared to those patients with lower BMI. There is a significant rise in ET-CO<sub>2</sub> in patients with body mass index (BMI) > 30. Obesity also poses concerns regarding the positioning of the patient and the equipment. In addition, intravenous access and non-invasive blood pressure measurement are also problematic.

Some researchers have tried to do RA pelvic surgeries in less than steep tilt position. Sasada et al have attempted to do RA hysterectomy with a lower tilt of operating table. They defined an angle of at least 30° as steep Trendelenburg and performed 38 cases in steep position and subsequently, they performed 12 cases in the reduced angle of average 16.6°. They did not find any increased operative time but blood loss decreased to half in cases with reduced angle. A single study done by Ghomi et al was found to relate minimal angle of Trendelenburg position required to do robotic gynecologic surgeries with BMI, age and surgical console time. They found that angle as low as 16° was equally effective to steep Trendelenburg position for procedures and there was no significant difference in console time, blood loss, and complications to the angle of Trendelenburg used.

### 2.8. Other concerns

Prolonged steep Trendelenburg position, without adequate chest stabilization and shoulder braces can lead to the risk of sliding cephalad off the head of the table of the patient. These stabilisation techniques, in turn, lead to certain physiological alterations. Like mentioned earlier, chest stabilisation leads to decreased pulmonary compliance. In addition, the shoulder braces can lead to compression or stretching of the nerves result in ischemia to the vasa nervosum. Thus caused ischemic injury is believed to be the main mechanism of brachial plexus injury. The incidence of brachial plexus injury in gynecologic laparoscopic or robotic surgery is approximately 0.16%.

There is a risk for lower extremity neuropathy in the immediate postoperative period due to prolonged lithotomy positioning. Manny et al. in their study reported an incidence of 1.7% postoperative neuropathies in a series of 179 patients who underwent robotic-assisted radical cystectomy. Prolonged surgeries can place patients at risk of rhabdomyolysis due to constant and prolonged pressure resulting in decreased blood flow and ischemia.

### 3. Conclusion

There are multi-systemic alterations in the physiological milieu of the patient due to the various equipment and non-physiological positions utilised in robotic-assisted surgeries. Detailed knowledge of such alterations is a must for the operating surgeons and the anaesthesiologists. Importantly, changes in the cardio-pulmonary, ocular, and intracranial systems due to lithotomy and steep Trendelenburg positions, and insufflation of pneumoperitoneum must be considered in the pre-operative, intra-operative and post-operative periods alike. The concerns raised from such changes in patients with and without any underlying systemic compromise should guide the surgeons and anaesthesiologists to envisage serious complications and intervene to prevent and treat them accordingly.

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None.

### 5. Conflict of Interest

The authors declare that there is no conflict of interest.

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