Background
  - history, current systems, politics and economics

Physiology Impact

Complications

Anesthetic Management

Future Perspectives
DEVELOPMENTS LEADING TO CURRENT ROBOTIC SURGICAL SYSTEMS
There are currently 1,548 Da Vinci robots in the US.

At the close of 2011, there were 2,132 Da Vinci systems installed at 1,718 facilities worldwide.
Surgical procedures employed:

- **Cardiac**: LIMA takedown with LAD anastamosis, Mitral valve repair.
- **Thoracic**: Mediastinal mass, Lobectomy.
- **Upper Abdominal**: Reflux surgery, Bariatric surgery, Diaphragmatic and Esophageal hernia surgery, Esophagectomy, Cholecystectomy.
- **Mid Abdominal**: Nephrectomy, Adrenalectomy, Colorectal.
- **Pelvic**: Prostatectomy, Hysterectomy, Cystectomy, Sacrocopolpexy, Myomectomy, Endometriosis.
- **Head and Neck**: Thyroidectomy, Cancer surgery.
THE LEARNING CURVE
THE LEARNING CURVE

Knowledge Development
Skills Training
Real Life Cases

- Knowledge and understanding of robotic technology.
- Functions and limitations.
- Trouble shooting.
- Procedure specifics;
  - patient selection,
  - indications,
  - preoperative preparation,
  - system positioning,
  - port placement,
  - procedural steps,
  - complications and management.
THE LEARNING CURVE

Knowledge Development
Skills Training
Real Life Cases

- Robot used for training exercises when not booked.
- Reusable models.
- Animal intestine.
- Virtual reality;
  - SEP robot simulator,
  - RoSS,
  - dV Trainer.
THE LEARNING CURVE

Knowledge Development
Skills Training
Real Life Cases

- Live case demonstrations.
- Bedside assistant.
- Proctoring.
- Mentoring.
The Learning Curve

Operating time

Basic outcomes

Advanced outcomes

Proficiency

- Set-up time.
- Docking time.
- Console time.
- Theater time.
- Average starting time of 424 min.
- 25% drop by ten cases.
- Plateau at 230 min at 77 cases.
Structured approach of 55-80 cases.

- Observe 10-20
- Bedside assistant 10-25
- Segmented time as a console surgeon 20-30
- Performing entire operation as primary surgeon, but under direct supervision of an experienced mentor.
COST OF ROBOTIC ASSISTED SURGERY

<table>
<thead>
<tr>
<th>Variables</th>
<th>RALP</th>
<th>LRP</th>
<th>RRP</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct cost, median (IQR)</td>
<td>6752 (6283–7369)</td>
<td>5687 (4941–5905)</td>
<td>4437 (3989–5141)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Surgical supply cost (fixed)</td>
<td>2015</td>
<td>725</td>
<td>185</td>
<td>–</td>
</tr>
<tr>
<td>Operating room cost, median (IQR)</td>
<td>2798 (2493–3175)</td>
<td>2453 (2130–2778)</td>
<td>1611 (1491–1995)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Anesthesia cost, median (IQR)</td>
<td>419 (378–464)</td>
<td>365 (297–411)</td>
<td>234 (189–297)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Medication cost, median (IQR)</td>
<td>297 (247–353)</td>
<td>271 (213–332)</td>
<td>272 (231–331)</td>
<td>0.0008</td>
</tr>
<tr>
<td>Lab cost, median (IQR)</td>
<td>295 (246–350)</td>
<td>386 (321–558)</td>
<td>659 (435–860)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Room and board cost</td>
<td>495 (495–990)</td>
<td>990 (495–990)</td>
<td>990 (990–1485)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Median (IQR)</td>
<td>778 (758)</td>
<td>873 (409)</td>
<td>1242 (678)</td>
<td></td>
</tr>
</tbody>
</table>

Direct cost was highest for Robotic procedure.
Surgical supply costs were $1,830 higher.
OR time costs were $1,187 higher.
Robotic cases made up $495 on earlier discharge.
Robotic Assisted surgery cost $2,315 (52%) more per case.
Cost of Robotic Assisted Surgery

52% increase in direct cost to the hospital.

- Maybe, ...
  - Jan. 2012 cost of da Vinci Si Firefly $2,185,000
  - Annual maintenance contract $150,000
  - Additional $3,667 per case
  - Total direct cost $10,419 vs. $4,437
Physiologic Impact
Physiology of Robotic Assisted Pelvic Surgery

Cardiovascular Effects of Trendelenburg and Pneumoperitoneum

15 – 20 degree Trendelenburg
- PCWP > 18 mm Hg
- CO fell by 10-30%

12 mm Hg Pneumoperitoneum
- MAP increased 25%
- CVP, MPAP, PCWP unchanged
- SVR increased 20%
- HR, SV, CO unchanged
- Mesenteric, hepatic and renal blood flow decreased.
PHYSIOLOGY OF ROBOTIC ASSISTED PELVIC SURGERY

45° Trendelenburg with Pneumoperitoneum for robotic assisted pelvic surgery.
- CVP, MPAP, PCWP doubled
- Blood pressure increased by 25%
- SVR initially increased, then normalized
- HR, SV, CO unchanged
- RV and LV stroke work increased by 65%

<table>
<thead>
<tr>
<th>Table 1. Hemodynamic, Ventilatory, and Gas Exchange Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumoperitoneum</td>
</tr>
<tr>
<td>Horizontal</td>
</tr>
<tr>
<td>Pneumo</td>
</tr>
<tr>
<td>Trend 5</td>
</tr>
<tr>
<td>Trend 45</td>
</tr>
<tr>
<td>Postsurgery</td>
</tr>
<tr>
<td>Heart rate, min⁻¹</td>
</tr>
<tr>
<td>SV, mL</td>
</tr>
<tr>
<td>Cardiac output, L· min⁻¹</td>
</tr>
<tr>
<td>MAP, mm Hg</td>
</tr>
<tr>
<td>MPAP, mm Hg</td>
</tr>
<tr>
<td>PCWP, mm Hg</td>
</tr>
<tr>
<td>CVP, mm Hg</td>
</tr>
<tr>
<td>SVR, dyne· min⁻¹· s⁻⁵</td>
</tr>
<tr>
<td>PVR, dyne· min⁻¹· s⁻⁵</td>
</tr>
<tr>
<td>LVSWI, g· m· m⁻²</td>
</tr>
<tr>
<td>RVSWI, g· m· m⁻²</td>
</tr>
</tbody>
</table>

Anesthesia Analgesia; November 2011, Volume 113, Number 5, 1069-1075
Physiology of Robotic Assisted Pelvic Surgery

- Filling pressures more than doubled.
  - CVP of a level associated with acute heart failure.
  - PA systolic pressures consistent with pulmonary hypertension in more than 75% of patients.
- Ventricular stroke work increased in majority of patients.
- Immediate postoperative hyperdynamic state.

- Patients with compromised systolic function may be pushed into acute failure.
- Patients with obstructive coronary disease may experience demand ischemia.
Echocardiographic measures of left and right ventricle function indicate preserved or slight increase in stroke volume.
Elevation in filling pressures was associated with 25% increase in early transmitral flow \((\text{early passive LV filling before atrial kick})\).

Preservation of isovolemic relaxation time and deceleration time would indicate diastolic function is well preserved.

Diastolic function as an early indication of ischemia indicate increases in filling pressure, afterload and stroke work are well tolerated.
Physiology of Robotic Assisted Pelvic Surgery

- Healthy non-anesthetized volunteers experienced a rise in heart rate without significant change in blood pressure or cardiac output.
- Patients with underlying ischemic heart disease saw a rise in blood pressure and cardiac output with a fall in heart rate.

The Journal of International Medical Research; 2011, 39, 1084-1089
Pulmonary Effects of Trendelenburg and Pneumoperitoneum

- Reduced total lung capacity, compliance and increase airway pressures.
- A 15 mm Hg pneumoperitoneum yields a 9 mm Hg rise in intrathoracic pressure.
- The diaphragm is shifted cephalad and FRC is reduced more than 50%. Lung volume approaches closing capacity with resultant atelectasis and shunt.
- Arterial oxygenation falls.
- Minute ventilation must increase to offset hypercarbia.
Ventilation modes and respiratory variables during TrP and PPN

- **Volume Control and Pressure Control at equal tidal volumes.**
- **Pressure Control yields better compliance and lower airway pressures.**
- **There were no statistically significant differences in hemodynamics.**
- **RR increased nearly 50% to maintain normal pCO2 levels.**

<table>
<thead>
<tr>
<th>Group</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
</tr>
</thead>
<tbody>
<tr>
<td>PaO2 (mmHg)</td>
<td>VCV</td>
<td>187 ± 39</td>
<td>168 ± 48 *</td>
<td>168 ± 53 *</td>
</tr>
<tr>
<td></td>
<td>PCV</td>
<td>196 ± 36</td>
<td>165 ± 42 *</td>
<td>175 ± 42 *</td>
</tr>
<tr>
<td>RR (breaths/min)</td>
<td>VCV</td>
<td>9 ± 1</td>
<td>14 ± 5 *</td>
<td>16 ± 5 *</td>
</tr>
<tr>
<td></td>
<td>PCV</td>
<td>8 ± 2</td>
<td>13 ± 2 *</td>
<td>15 ± 3 *</td>
</tr>
<tr>
<td>Cdyn (mL/cmH2O)</td>
<td>VCV</td>
<td>43.1 ± 6.0</td>
<td>16.1 ± 2.1 *</td>
<td>15.5 ± 1.8 *</td>
</tr>
<tr>
<td></td>
<td>PCV</td>
<td>42.8 ± 6.3</td>
<td>18.9 ± 3.0 *-↑</td>
<td>18.6 ± 3.6 *-↑</td>
</tr>
<tr>
<td>APpeak (cmH2O)</td>
<td>VCV</td>
<td>12.9 ± 2.0</td>
<td>34.0 ± 3.5 *</td>
<td>35.7 ± 4.7 *</td>
</tr>
<tr>
<td></td>
<td>PCV</td>
<td>12.3 ± 1.6</td>
<td>29.2 ± 5.0 *-↑</td>
<td>29.0 ± 5.8 *-↑</td>
</tr>
<tr>
<td>APmean (cmH2O)</td>
<td>VCV</td>
<td>3.5 ± 1.2</td>
<td>9.5 ± 1.5 *</td>
<td>9.0 ± 1.5 *</td>
</tr>
<tr>
<td></td>
<td>PCV</td>
<td>3.8 ± 0.8</td>
<td>10.2 ± 2.0 *</td>
<td>10.0 ± 2.1 *</td>
</tr>
<tr>
<td>Estim. Vd/Vt (%)</td>
<td>VCV</td>
<td>6.5 ± 4.6</td>
<td>14.6 ± 10.1 *</td>
<td>15.9 ± 9.8 *</td>
</tr>
<tr>
<td></td>
<td>PCV</td>
<td>6.3 ± 5.8</td>
<td>12.0 ± 8.4 *</td>
<td>15.5 ± 9.1 *</td>
</tr>
<tr>
<td>Qs/Qh (%)</td>
<td>VCV</td>
<td>11.3 ± 4.2</td>
<td>12.4 ± 6.8</td>
<td>11.0 ± 5.4</td>
</tr>
<tr>
<td></td>
<td>PCV</td>
<td>9.1 ± 4.0</td>
<td>11.9 ± 5.2</td>
<td>10.3 ± 5.8</td>
</tr>
</tbody>
</table>

Journal of Clinical Anesthesia; 2011, 23, 183-188
Effects of PEEP during TrP and PPN

Application of 5 mm Hg PEEP increases FRC, elevating lung volumes above closing capacity.

- Less atelectasis.
- Compliance improves.
- Arterial oxygenation improves.

*Pneumoperitoneum with addition of PEEP may abruptly drop CO.*
PHYSIOLOGY OF ROBOTIC ASSISTED PELVIC SURGERY

Abdominal Effects of Elevated Intra-abdominal Pressure Pneumoperitoneum

- Blood is mobilized out of the abdominal viscera, causing an acute increase in cardiac preload.
- Blood flow through the mesenteric arteries decreases, resulting in a slow gradual rise in mucosal pH related to gut ischemia.
- Portal vein, hepatic vein and hepatic tissue perfusion all decrease with associated rise in transaminases.
- Blood flow in both the renal cortex and medulla decreases with resultant fall in urine output.
- Elevated intra-abdominal pressure may decrease return through the IVC and may result in delayed drop off in cardiac pre-load.
PHYSIOLOGY OF ROBOTIC ASSISTED PELVIC SURGERY

Effect of Elevated Pressure Pneumoperitoneum on Neurohormonal regulation.
- Rise in vasopressin and norepinephrine.
- Activation of renin-angiotensin system.
Physiology of Robotic Assisted Pelvic Surgery

Cerebral Hemodynamics during steep Trendelenburg and Pneumoperitoneum

- Head-down positioning increases CVP and thus impairs venous drainage of the head.
- The elevation of hydrostatic forces can lead to an increase in extracellular water and perivascular edema.
- Development of cerebral edema and elevations in ICP may lead to increased cerebrovascular resistance and reduced cerebral blood flow.
- ICP may be further elevated by increases in cerebral blood volume related to hypercarbia.
- Impedance of drainage of the lumbar venous system secondary to the elevated intra-abdominal pressure may decrease reabsorption of CSF and lead to a rise in ICP.
Physiology of Robotic Assisted Pelvic Surgery

Transcranial Doppler studies

- Pulsatility and resistivity unchanged.
- Zero flow pressure increases in parallel with CVP.
- The gradient between calculated CPP and effective CPP unchanged.
- Cerebral perfusion is well preserved after 3 hours.

No indication of a increase in perivascular tissue resistance.
Near-infrared spectroscopy

- Measures of cerebral oxygenation do not indicate cerebral ischemia.

Acta Anaesthesiologica Scandinavica; 2009, 53, 895-899
Intraocular Pressure Dynamics during steep Trendelenburg and Pneumoperitoneum

Major determinants of IOP
- Aqueous humor flow
- Choroidal blood volume
- CVP
- Extra-ocular muscle tone

_Intraoperative hypertension, hypercarbia, position and elevation in CVP may lead to elevated IOP._
Physiology of Robotic Assisted Pelvic Surgery

Tonometry measures of IOP

- Patients reached elevated IOP levels averaging 13 mm Hg above baseline, comparable to glaucoma.
- There was a time and EtCO2 dependant component of this increase.
PHYSIOLOGY OF ROBOTIC ASSISTED PELVIC SURGERY

Findings of effect on IOP

- Increases in systemic blood pressure, CVP and airway pressure all contribute to a rise in IOP.
- IOP continues to rise through time in the head-down position.

<table>
<thead>
<tr>
<th>Variable</th>
<th>P</th>
<th>Slope coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.5941</td>
<td>0.035</td>
</tr>
<tr>
<td>BMI</td>
<td>0.4754</td>
<td>−0.0857</td>
</tr>
<tr>
<td>Blood loss</td>
<td>0.0133</td>
<td>−0.0258</td>
</tr>
<tr>
<td>IV fluid intake</td>
<td>0.8945</td>
<td>0.0002</td>
</tr>
<tr>
<td>ETco₂</td>
<td>&lt;0.0001</td>
<td>0.5560</td>
</tr>
<tr>
<td>Peak airway pressure</td>
<td>&lt;0.0001</td>
<td>0.7787</td>
</tr>
<tr>
<td>Plateau airway pressure</td>
<td>&lt;0.0001</td>
<td>2.1065</td>
</tr>
<tr>
<td>Mean arterial blood pressure</td>
<td>&lt;0.0001</td>
<td>0.0916</td>
</tr>
<tr>
<td>Time</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
COMPLICATIONS
EBL 109 (50-750) mL
1.3% postop anemia
1% postop transfusion

3% corneal abrasion
0.6% reoperation
- Bleeding
- Bowel injury
- Hernia
0.2% PE
0.2% da Vinci failure
0.06% prolonged intubation
COMPLICATIONS

Failure of a robotic arm during da Vinci prostatectomy: a case report

Nikolaos Kolakis · Geert Denayer · Peter Willensen · Peter Schatsierman · Alexander Mostric

Received: 20 December 2007 / Accepted: 7 April 2008 / Published online: 24 April 2008
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Abstract We report a rare case of a da Vinci robotic arm failure during a laparoscopic radical prostatectomy. The articulation joint of an EndoWrist needle driver was broken and positioned at such an angle that made it impossible to remove through the trocars. In addition, it was later discovered that a small piece of the instrument was detached and remained inside the abdomen of the patient without even having been identified on subsequent radiological evaluation. In order to remove the broken instrument, we had to unmount it from the robot arm and a bigger incision had to be made in the abdominal wall of the patient. The operation was completed without any other incidents. Testing the broken instrument for integrity is recommended to avoid this rare complication.

Keywords Broken arm · Complication · da Vinci robot · Failure · Radical prostatectomy

Introduction

Robot-assisted radical prostatectomy is gaining ground in the therapy of localized prostate cancer. As the number of centers grows and the number of operations performed multiplies, it is possible that rare complications regarding the robot hardware or software will appear that will need the doctor’s intervention outside the normal procedure. We present a rare complication of the da Vinci robot intuitive Surgical, CA, USA) hardware during a laparoscopic robotic-assisted radical prostatectomy.

Case report

A 59-year-old patient with a T2b prostate cancer was scheduled for a transperitoneal robotic prostatectomy. The operation setting included a four-arm da Vinci 5 system with the fourth arm on the left to allow for the surgeon’s right hand to be placed on the patient’s left side. The right arm of the robot was loaded with a Maryland biopsy forceps, a left sheath was mounted on the left (second) arm and a large needle driver was mounted on the third (left) arm. During the operation and specifically after finishing the dissection of the pelvic fascia the surgeon put aside the main left arm and used the secondary left arm with the needle driver. In doing so we realized that the EndoWrist articulation of the needle driver was dislodged and the instrument was insecure (Fig. 1). We tried to remove the instrument but it was impossible to pass it through the port. An attempt to straighten the dislocated joint with the other robot instruments was unsuccessful (Fig. 2). Finally, we had to unmount the port from the robot arm, re-ligate the abdominal incision, and re-secure the trocar and instrument together. The incision was closed, a new needle driver was fixed and the operation completed uneventfully. No postoperative complications were noticed.

Discussion

In our center we have performed 520 robot-assisted radical prostatectomies in the past 5 years. During these we have experienced three software malfunctions that just needed removal then reinstallation of the instruments, one loss of
ROBOTIC SYSTEM MALFUNCTION

Review of 1,914 reports of da Vinci malfunction reported to FDA.

- Instrument failures comprise the largest group.
  - Arcing
  - Fragmentation
- Patient side cart malfunctions.
- Console malfunction.
- Endoscope malfunction.
ROBOTIC SYSTEM MALFUNCTION
Robotic System Malfunction

British Journal of Urology International; 2011, 109, 1222-1227
Robotic System Malfunction

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Console (%)</td>
<td>71 (5.3)</td>
<td>49 (9.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Patient-side cart (%)</td>
<td>91 (6.8)</td>
<td>57 (10.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Instruments (%)</td>
<td>965 (74.2)</td>
<td>379 (72.3)</td>
<td>0.410</td>
</tr>
<tr>
<td>Endoscope (%)</td>
<td>41 (3.1)</td>
<td>13 (2.5)</td>
<td>0.505</td>
</tr>
<tr>
<td>No malfunction (%)</td>
<td>29 (2.2)</td>
<td>5 (1.0)</td>
<td>0.080</td>
</tr>
<tr>
<td>Other malfunctions (%)</td>
<td>114 (8.5)</td>
<td>21 (4.0)</td>
<td>0.001</td>
</tr>
<tr>
<td>Total malfunctions</td>
<td>1341</td>
<td>524</td>
<td></td>
</tr>
<tr>
<td>Conversions (%)</td>
<td>Open 131 (9.9)</td>
<td>Open 106 (21.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Aborted procedures (%)</td>
<td>45 (3.4)</td>
<td>7 (1.4)</td>
<td>0.024</td>
</tr>
<tr>
<td>Injury (%)</td>
<td>41 (3.1)</td>
<td>12 (2.3)</td>
<td>0.282</td>
</tr>
<tr>
<td>Death</td>
<td>22</td>
<td>1</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>dV</th>
<th>dVS</th>
<th>P</th>
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</thead>
<tbody>
<tr>
<td>Conversions (%)</td>
<td>Open 10 (1.2)</td>
<td>Open 10 (1.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Aborted procedures (%)</td>
<td>Lap 163 (19.3)</td>
<td>Lap 75 (17.7)</td>
<td></td>
</tr>
<tr>
<td>Procedure delay</td>
<td>Minor 14 (17)</td>
<td>Minor 28 (2.9)</td>
<td>0.093</td>
</tr>
<tr>
<td>Injury (%)</td>
<td>Major 17 (2.0)</td>
<td>Major 57 (6.9)</td>
<td>0.021</td>
</tr>
<tr>
<td>Death</td>
<td>4</td>
<td>19</td>
<td>0.002</td>
</tr>
</tbody>
</table>

British Journal of Urology International; 2011, 109, 1222-1227
COMPLICATIONS OF PNEUMOPERITONEUM

Laparoscopy and Robotics

Detection of Subclinical CO₂ Embolism by Transesophageal Echocardiography During Laparoscopic Radical Prostatectomy

Jeong-Yeon Hong, Won Oak Kim, and Hae Keum Kil

OBJECTIVES
To document incidences of subclinical embolism in laparoscopic radical prostatectomy with continuous monitoring using transesophageal echocardiography (TEE).

METHODS
A total of 43 patients scheduled for elective robotic-assisted laparoscopic radical prostatectomy under general anesthesia were enrolled in this study. A 4-chamber view of 5.0-MHz multiplane TEE was continuously monitored to detect any intracardiac bubbles as an embolis. An independent TEE specialist reviewed the tapes for interpretation, and emboli were classified as 1 of 5 stages. Cardiorespiratory instability during gas emboli entry was defined as an appearance of cardiac arrhythmias, sudden decrease in mean arterial blood pressure >20 mm Hg, or an episode of pulse oximetric saturation <90%.

RESULTS
Gas embolisms were observed in 7 of 41 (17.1%) patients during transection of the deep dorsal venous complex. Of them, 1, 3, 1, and 2 showed stage I, II, III, and IV, respectively. However, there were no signs of cardiorespiratory instability associated with emboli. The 95% confidence interval for gas embolism was 0.204%-0.138%. No correlation was observed between episodes of gas embolism and blood gas variables or end-tidal CO₂ partial pressure.

CONCLUSIONS
Subclinical gas embolisms occur in 17.1% of laparoscopic radical prostatectomies. We should consider that this procedure has a potential for serious gas embolism, especially with the increasing popularity of laparoscopic prostatectomy using robot-assisted techniques. 

17% prostatectomy
6% nephrectomy
69% cholecystectomy
68-100% liver resection

Complications of Pneumoperitoneum

Subcutaneous Emphysema

- Common ~5%.
- Usually self limited.
- Increases rate of CO² uptake.
  - Progressive mixed acidosis.
  - Continued postoperative absorption.
- Further investigation
  - Pneumothorax
  - Capnothorax
  - Pneumomediastinum

Complications of Pneumoperitoneum

The displacement of the tracheal tube during robot-assisted radical prostatectomy
Chul Ho Chang, Hyun Kyu Lee and Soon Ho Nam

Background and objective Robot-assisted prostatectomy requires pneumoperitoneum in a steep Trendelenburg position, which may induce endobronchial intubation or accidental extubation. The aim of the study was to evaluate the effect of pneumoperitoneum in 30° Trendelenburg position on the displacement of the tracheal tube and to measure the changes in tracheal length using fiberoptic bronchoscope.

Methods Thirty male patients scheduled for robot-assisted radical prostatectomy were enrolled. After induction of general anesthesia, the distance between the vocal cords and the tracheal tube tip (AVE), between the tracheal tube tip and the carina (ΔEC) and between the vocal cords and the carina (ΔVC) was measured using a fiberoptic bronchoscope before and 10 min after pneumoperitoneum in neutral position (T1) and 2 h after pneumoperitoneum in 30° Trendelenburg position (T2).

Results The ΔVC and ΔEC decreased significantly 10 min after pneumoperitoneum in neutral position (T1) and 2 h after pneumoperitoneum in Trendelenburg position (T2) compared with those before pneumoperitoneum in neutral position (T1) (all P<0.001). The changes in ΔVE were not statistically significant.

Conclusion The formation of the tracheal tube position is recommended after pneumoperitoneum in steep Trendelenburg position during robot-assisted prostatectomy because the displacement of the tracheal tube may result in endobronchial intubation due to shortening of the carina-to-tube tip distance.


Keywords tracheal tube, pneumoperitoneum, robot-assisted radical prostatectomy, Trendelenburg position.

Received 2 June 2008 Revised 7 September 2009 Accepted 5 October 2008

Changes of the airway distance. Changes of the distance between vocal cord and carina (VC). Mean values are expressed as circle. Error bars indicate SD. Changes of the distance between vocal cord and tracheal tube tip (VE). Mean values are expressed as triangle. Error bars indicate SD. Changes of the distance between endotracheal tube tip and carina (EC). Mean values are expressed as square. Error bars indicate SD. Control, before pneumoperitoneum and Trendelenburg position; 10 min, 10 min after pneumoperitoneum; 2 h, 2 h after pneumoperitoneum and Trendelenburg position. EC, distance between the tracheal tube tip and the carina; VC, distance between the vocal cords and the carina; VE, distance between the vocal cords and the tracheal tube tip. *P<0.001 compared with control.
Intra-abdominal Fire Due to Insufflating Oxygen Instead of Carbon Dioxide During Robot-Assisted Radical Prostatectomy: Case Report and Literature Review

Giovanni B. Di Pierro, Ivo Besmer, Lukas J. Hefermehl, Josef Beatrice, Hansjörg Danuser, Jonas Beutler, Agostino Mattei

Case Series of the Month

Abstract

We report the first case of intra-abdominal combustion involving the plastic covering of monopolar scissors secondary to use of incorrect gas (oxygen [O₂] instead of carbon dioxide [CO₂]) during robot-assisted laparoscopic radical prostatectomy (RALP). The insufflating system was connected to a provisional O₂ gate into the operating theater.

A patient underwent RALP and extended pelvic lymph node dissection for localized prostate cancer, according to standard technique. Approximately 1.5 h after the start of surgery, flames arose from the scissor tips during monopolar coagulation. After extinguishing the fire, we promptly withdrew and changed instruments before recognizing and resolving the cause of the incident.

The procedure was carried out without patient injury, and the postoperative period was uneventful.
Complications of Access

Aortic injury.

Robotically repaired.

Journal of Endourology; 2011, Volume 25, Number 2, 235-238
INNOCENT BYSTANDER INJURY

Iliac Vein hemorrhage.

Bowel perforation.

Yonsei Medical Journal; 2011, Volume 52, Number 2, 365-368

World Journal of Urology; Volume 26, Number 6, 595-602
CARDIOVASCULAR COMPLICATIONS

Cardiac Arrest

- Robotic arm pressed against patients neck

Vagal nerve mediated response; bradycardia, nodal, atrioventricular dissociation, asystole.

Catecholamine mediated response; sinus tach, ventricular extrasystole.
CARDIOVASCULAR COMPLICATIONS

Myocardial Infarction

- Patient had pre-existing coronary artery disease
- Coronary stents in-situ
- Taken off antiplatelet drugs prior to surgery

Congestive heart failure, refractory hypertension.
PULMONARY COMPLICATIONS

Pulmonary Edema

- IAP raised from 15 to 20 mm Hg
- 30 degree Trendelenburg
- CVP 31 cm H2O
- Compression of lung
- Absorption of crystalloid irrigating fluid

Barotrauma, atelectasis, pneumothorax, capnothorax.
Peripheral Neuropathy 0.25-1.5%
Median, Radial.  Ulnar.
Brachial plexus.
Sciatic, obturator, peroneal, lateral femoral cutaneous.
Self limited neuropraxia 15%
Compartment Syndrome

- Lithotomy-Trendelenburg
- Surgery over 4.5 hours
- Muscular calf muscles
- Blood loss
- Hypotension
- Vasoactive drugs
- Fibrate monotherapy
- Intermittent pneumatic compression devices
- Elevated BMI
CNS Complications

Paradoxical Cerebral Air Embolism

- 45 degree Trendelenburg
- CVP 8-16

Cerebral hemorrhage.
CNS Complications

Original Contribution

Posterior Ischemic Optic Neuropathy After Minimally Invasive Prostatectomy

Eric D. Weber, MD, Marcus H. Colyer, MD, Robert L. Lesser, MD, and Prem S. Subramanian, MD, PhD

Abstract: Two patients developed postoperative ischemic optic neuropathy (ION) after laparoscopic radical prostatectomy. One operation was robotically assisted; the other was performed with the conventional laparoscopic technique. These new minimally invasive techniques offer many advantages, but they require steep supine head-flexed (Trendelenburg) positioning. Until they are mastered by surgeons, operative times may be prolonged beyond those associated with the traditional technique. As a result, ION may occur more frequently.

ANESTHETIC CARE
PRE-OPERATIVE

History and Physical Exam

- General Medical Assessment.
- Patient specific factors which may be of concern with prolonged pneumoperitoneum or extremes of positioning.
- Patient specific factors which may contribute to a difficult procedure.

- Testing, blood work and consults driven by standard process.
Nervous system evaluation

- CVA
- Aneurysm
- Elevated ICP
  - Hydrocephalus, VP shunt
  - Head trauma
- Ocular pathology
  - Glaucoma
- Pre-existing neuropathy or susceptibilities
  - Diabetes, chemotherapy, peripheral vascular disease
  - Extremes of body size, surgery lasting > 3 hours.
Cardiovascular Evaluation

- Cardiomyopathy
- CAD or MI by history or symptoms
  - Angina
  - Untreated obstructive coronary disease
- Cardiac murmurs
  - Evaluated by Echo
  - Moderate or severe regurgitant valvular lesions
  - PFO
- Peripheral vascular disease
Pulmonary Evaluation

- COPD
- Bullous emphysema
- Spontaneous pneumothorax
- Reactive airway disease
- Prolonged pneumoperitoneum is contraindicated in moderate to severe disease states.
Renal disease

- Renal insufficiency
  - may benefit from protective strategies.
- Renal failure
  - Contraindication to prolonged pneumoperitoneum.
Lithotomy and Trendelenburg positioning
- For every one hour spent in lithotomy, risk of nerve injury increases 100 fold.
- Risks of compartment syndrome
  - Myopathy, Fibrates or statin use, Muscular calf, PVD

Lateral decub positioning
- Cervical spine disease
- Back pain, foraminal stenosis, radiculopathy
- Age
  - Increased risk of post operative ventilation (> 65 years old)
  - Increased risk of ICU admission
- Obesity
  - Correlated with longer operative times.
  - Higher ventilatory pressures and risk of barotrauma.
  - Lower intra-operative oxygenation,
  - Associated with OSA, airway difficulty, diabetes, ...
- Diaphragmatic hernia
- Coagulopathy
- Sickle cell disease
Patient specific factors making for a difficult operation.

- Morbid obesity
- Adhesions
- Prior surgery
- Prior infection
- Prior radiation
- Procedure specific
## Pre-Operative

<table>
<thead>
<tr>
<th>Pneumoperitoneum</th>
<th>Steep Trendelenburg</th>
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<tbody>
<tr>
<td>Systolic Failure</td>
<td>Intracranial Pathology</td>
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<tr>
<td>Diastolic Failure</td>
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<tr>
<td>Severe CAD</td>
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<td>COPD</td>
<td>Ocular Pathology</td>
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<td>Glaucoma</td>
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<td>Renal insufficiency</td>
<td>Head and Neck</td>
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<td>Vascular Abnormality</td>
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<td>Mesenteric ischemia</td>
<td>Valvular regurgitation</td>
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<td>Dilated cardiomyopathy</td>
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<td>Obese ventilation</td>
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</tbody>
</table>
**PRE-OPERATIVE**

- stop all antiplatelet medications for 1 week and ASA in radical prostatectomies
- 1 day before surgery should adhere to clear liquid diet.
- Night before use laxative suppositories.
  - Bowel prep not used.
- NPO at midnight.
- Psychological preparation
  - Should be aware of plan for early discharge.
  - Informed of known side effects and complications which are within the realm of normal and do not affect recovery or discharge.
PRE-OPERATIVE

- Blood Type and Antibody Screen.
- Peripheral IV access x 2.

- Premedication for multimodal analgesia.

- Antibiotic order.

- Antithrombotic prophylaxis with Heparin 5,000 IU subQ
- Antigastric prophylaxis with Ranitidine and sodium citrate.
CONDUCT OF ANESTHESIA

- Monitors
  - Standard ASA monitors

- Orbicularis oculi twitch response is most similar to the adductor pollicis in onset and duration.
CONDUCT OF ANESTHESIA

- Monitors for special circumstances
  - *Invasive monitors are indicated with inexperienced robotic programs or while a surgeon is inexperienced with a particular procedure.*
  - Arterial blood pressure monitoring is indicated for patients with cardiac or pulmonary disease, with all cystectomy or nephrectomy operations and procedures planned for greater than four hours.
  - Central line placement for the purpose of resuscitative drug administration warrant re-consideration if robotic surgery is the appropriate approach.
CONDUCT OF ANESTHESIA

- Monitors for special circumstances

  - Cardiac output monitoring is indicated in cardiomyopathy.
    - Esophageal doppler has been advocated by several authors.
  - TransEsophageal Echocardiography is the most advantageous monitor to add in the event of unexpected hemodynamic collapse.
CONDUCT OF ANESTHESIA

- Induction

- Intubation
  - Be aware of additive difficulty of intubation brought by bean bag positioners.
  - Note the depth of ETT relative to the carina.
  - Ensure endotracheal tube is well secured.
CONDUCT OF ANESTHESIA

- General Endotracheal Anesthesia
  - Secure airway.
  - Controlled mechanical ventilation to properly handle carbon dioxide absorbed through pneumoperitoneum.
  - Continuous neuromuscular blockade until robot is undocked.
  - Nitrous oxide +/-.
  - Low dose opioid.

- Neuraxial techniques not currently recommended.
  - Thoracic epidural is associated with earlier return of bowel function and of benefit in cystectomy with ileal conduit.
Once the robot is docked there is no further repositioning of the patient or bed without undocking the robot.

Care must be taken the patient is positioned well enough to tolerate up to 9 hours in the final position.
POSITIONING

Robotic Pelvic Surgery

- Lithotomy
- 30 – 45° Trendelenburg
- Arms tucked
Positioning

Preparation
OR Table
Gelmat
EggCrate
Beanbag
POSITIONING

- Supine
- Arms tucked
- Hands remain neutral
- Palms facing sides or pronated.
Positioning

- Supine
- Arms tucked.
- Upper extremity padded;
  - Ulnar nerve
  - Radial and Median nerve
- Secure but not tight.
- Protected from external compression.
Positioning

- Supine
- Advanced to Lithotomy
- Legs raised together
- Hip Abduction < 30°
- Hip Flexion > 45°
POSITIONING

- Lithotomy
- 30-45° Trendelenburg
- Test positioning security prior to prep and drape.
- Also verify ability to ventilate whenever in question.

Allen Hug U Vac® steep Trendelenburg positioner
Yellowfins Ellite® stirrups
POSITIONING

- Lithotomy
- 30-45° Trendelenburg
- Nautical inclinometer mounted to bed to facilitate rapid and accurate TrP.
POSITIONING

Monitoring of Adductor Pollicis train-of-four response using pulse oximetry

POSITIONING

Sequence for Lithotomy – Steep Trendelenburg positioning

- Awake tucking of arms.
- Induction and intubation.
- Eyes lubed. Tegaderm applied.
- Orogastric tube passed and gut decompressed.
- Ensure face will be clear of equipment;
  - protective padding placed if necessary.
- Fingers protected from bed hinges.
- Legs raised simultaneously to bilateral stirrups.
- Apply nerve stimulator.
- Apply the bean bag ensuring no pressure points created.
- Test the security of patient to bed in steep TrP.
- Visualize face at all times.
**Intraoperative Management**

- **Ventilation**
  - *A fall in compliance will complicate ventilation in TrP.*
  - Pressure Control Ventilation [PEEP + 20 (max)] is recommended.
  - PEEP [5 cm H2O] is recommended.
  - Mild hyperventilation to avoid development of hypercarbia and resultant metabolic and respiratory acidemia.
    - Suggested minute ventilation is 12-15 L/min.
    - Alternatively use twice the pre-PPN minute ventilation.
    - All changes in minute ventilation should be made through manipulation of respiratory rate, not tidal volume.
  - ETCO2 should plateau by 15-20 min.
    - Appropriate to correlate to ABG in at risk patients.
  - Anticipate endobronchial intubation or mechanical obstruction in PPN.
INTRAOPERATIVE MANAGEMENT

- **Perfusion**
  - Patients at risk of cardiomyopathy may benefit from arteriovasodilators
    - ie nicardipine
  - Patients at risk of demand ischemia may benefit from alpha two agonist
    - ie clonidine or dexmeditomidine
  - Patients at risk of elevated intracranial pressure should be protected
    - mannitol, fluid restriction, normocapnia.
  - Patients at risk of renal insufficiency should be protected
    - Mannitol, nicardipine infusion, warm insufflation.
  - Patients at risk of compartment syndrome should have calves checked for tissue tugor and consider repositioning legs every two hours.
INTRAOPERATIVE MANAGEMENT

- Neuromuscular blockade
  - Absolute requirement for paralysis during period which the robot is docked to the patient.
  - Use of continuous infusion has been advocated.
  - Monitoring of neuromuscular function by train of four has been recommended.
INTRAOPERATIVE MANAGEMENT

- Temperature management
  - Over the body forced air warmer above the xiphoid
  - Isothermic carbon dioxide
Intraoperative Management

- Fluid Management
  - Excess fluid administration in steep TrP can lead to facial edema with associated swelling of conjunctiva and/or airway.
    - In prostatectomy, fluid restriction is warranted with a goal of less than 1 liter IVF up to the completion of the urethrovesical anastomosis.
    - After the urethrovesical anastomosis is complete, liberalize fluid administration with the goal of an additional 1 liter IVF by the end of surgery.
  - Always discuss concerns regarding fluid status with surgeon.
  - Have a lower than usual threshold for colloid administration.
INTRAOPERATIVE MANAGEMENT

- Other intra-operative issues.
  - Thromboprophylaxis
    - Elevation of the legs and placement to stirrups raises the risk of DVT formation.
    - TED hose can further elevate this risk while in the lithotomy Trendelenburg position.
    - Intermittent Compression Devices lower DVT risk and promote venous return to the heart even with elevated intra-abdominal pressure.
    - Pre-operative SQ Heparin is standard practice
Intraoperative Management

- Other intraoperative issues.
  - Oral, facial and ocular burns have been associated with regurgitation of stomach acid in TrP.
    - Orogastric decompression
    - H2 blockade
    - Carefully cover the eyes with Tegaderm.
  - Antiemetic prophylaxis.
  - Surgical Local Anesthetic
    - Trocar / port site infiltration 5 – 10 mL
    - Intraperitoneal installation 40 mL
  - Irrigation fluid and urine commonly overwhelm blood in the suction canisters making estimating blood loss difficult.
PNEUMOPERITONEUM

- Isothermic (37°) carbon dioxide if possible.
  - Recommendations state “to use the lowest IAP allowing adequate exposure ... to avoid more than 12 mm Hg combined with Trendelenburg positioning because it reduces pulmonary compliance ... and worsens ventilation-perfusion impairment.”

- Low pressure 5-7 mm Hg
  - Splanchnic perfusion preserved.

- Normal 12 mm Hg

- High 15-20 mm Hg;
  - may be enacted to tamponade venous bleeding.

- Anticipate bradycardia [asystole] with raising pneumoperitoneum and initial placement of ports.

- Reassess for bilateral breath sounds to exclude endobronchial intubation.
EMERGENCY PLANNING

- Have a low threshold for advanced monitoring and arterial blood gas analysis.
- Cardiovascular instability warrants immediate termination of PPN and TrP and, if refractory, investigation with transesophageal echo.
- Advocate for aborting or suspending robotic technique if signs indicate patient is not tolerating steep TrP.
- Have a plan for management of massive hemorrhage.
- Review management of CO2 embolism.
- Be prepared to emergently undock robot ASAP.
- It is acceptable to cardiovert with the robot docked.
PREPARING FOR EMERGENCE

- Terminate neuromuscular blocker administration once the robot is undocked.
- Use “sigh” breath or recruitment maneuvers to reverse interval atelectasis from PPN or endobronchial intubation.
- Elevate the patient’s head as soon as is permissible.
- Maintain mechanical ventilation and hyperventilation until the patient awakens.
- Forego additional narcotic administration until PACU.
Delayed awakening is common.

- Cerebral edema
- Hypercarbia
- Commonly editorialized but poorly explained.
**EXTUBATION**

Anticipate a delay in awakening.

- Elevate the head of bed.
- Assess for subcutaneous emphysema.
- Assess for head and neck swelling, and scleral and periorbital edema.
- Perform endotracheal tube cuff “**leak test**”.
- Ensure patient is following commands.
- Auscultate for clear, bilateral breath sounds.
- Ensure return of neuromuscular function.

If in any doubt of appropriate wakefulness, adequacy of ventilation, or ability to maintain a patent airway - **do not extubate**.
POSTOPERATIVE

- Standard monitors for recovery of general anesthesia.
  - Maintain elevation of the head of bed.
  - Hemoglobin analysis is indicated.
  - Blood gas analysis is indicated in the presence of hypoxia, delirium, hyperventilation or as follow up to intraoperative ABG abnormality.
  - Chest radiographs are indicated when significant subcutaneous emphysema is present, or if there are signs suggesting pneumothorax, or unexplained low oxygen saturations.
  - NSAID analgesia - if the surgeon is agreeable.
POSTOPERATIVE

- Patients should require little additional narcotic.
  - Reported pain should be evaluated as consistent with procedure, referred from phrenic nerve irritation, or related to intraoperative positioning.
  - Moderate or severe pain should prompt evaluation by surgeon.

- Mental status should be evaluated to rule out hypercarbia, elevated intracranial pressure and stroke.
- Positional neuropathies if any, need to be looked into.
- Oliguria should be promptly treated with 500 mL bolus of crystalloid and then continue at 150 mL/Hr. Primary service should be notified.
ROBOTIC SURGERY OF UPPER ABDOMEN

General Surgery

- Principles to Laparoscopic Surgery
  - Reverse Trendelenburg
  - Pneumoperitoneum
  - Often one arm is out

- Hypovolemic hypotension
  - Pre-op replacement of intravascular deficit

- Robot is docked above patient’s head
  - Risk of collision
  - Limited access

- Risk of tension pneumothorax

Bariatrics, antireflux, gastrectomy, esophageal procedures, cholecystectomy.
TRANSORAL ROBOTIC SURGERY

TORS
- Basic principles of ENT
- Used for low grade lesions only.
- Wire re-inforced ETT
- ETT sewn in place
- Patient eye protection
- Dental guard
- TIVA
- 24-48 hrs post op ventilation

Radical tonsillectomy, supraglottic partial laryngectomy, pharyngectomy, base of tongue resection, thyroidectomy.
Chief Concerns for Anesthesia during Robotic Assisted Surgery

- Limitation of access.
- Inexperience of surgeon, assistants or team.
- Extremes of patient positioning.
- Length of case.
- Hypothermia.
- Respiratory and hemodynamic effects of pneumoperitoneum and extremes of positioning.
- Occult blood loss.
- Unsuspected visceral injury.
Anesthesia robots
Robotics in Anesthesia

Orchestra (PharmaCo)

- Targeted infusion system.
- Remifentanil
- Propofol
- Vecuronium
Robotics in Anesthesia

McSleepy (McGill University)

Integrated Monitor of Anesthesia (IMA)
- Depth of anesthesia via EEG.
- Pain via the Analgoscore.
- Muscle relaxation via phonomyography.

Closed loop system which administers drugs, monitors their effects and adjusts further administration.
Robotics in Anesthesia

Kepler Intubation System (KIS)

- Robotically mounted video laryngoscope.
Robotics in Anesthesia

Da Vinci robotic assisted nerve block
Robotics in Anesthesia

Da Vinci robotic assisted intubation
FUTURE DIRECTIONS
Stanford Research International
- M7 dexterous manipulator
- Development for open surgery
Stanford Research International
- M7 dexterous manipulator
- Compact and portable
Stanford Research International
- M7 dexterous manipulator
- Being applied to a fully robotic OR
  - Traumapod
Thank you