Effects of Prolonged Pneumoperitoneum on Hemodynamics and Acid–Base Balance during Totally Endoscopic Robot-assisted Radical Prostatectomies

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Abstract. Laparoscopic techniques have become a standard approach for diagnostic and therapeutic procedures in many surgical disciplines. Recent progress in endoscopic surgery is based on the integration of computer-enhanced telemanipulation systems. Because robot-assisted radical prostatectomies take up to 10 hours, the present study was performed to evaluate the effects of prolonged intraabdominal CO2 insufflation on hemodynamics and gas exchange in 15 patients with prostate cancer. When CO2 insufflation was initiated, peak inspiratory pressure increased and reached significant values after a 1.5-hour period of intraperitoneal CO2 insufflation. With the release of CO2, peak inspiratory pressure decreased close to baseline values. A significant increase in heart rate was observed after a 4-hour period of increased intraabdominal pressure. Mean arterial blood pressure and central venous pressure remained stable during CO2 insufflation. Minute ventilation was adjusted according to repeated blood gas analyses to maintain pH, base excess (BE), bicarbonate (HCO3-), and PaCO2 within physiologic ranges. The present data show, that prolonged CO2 insufflation during totally endoscopic robot-assisted radical prostatectomy results in only minor changes in hemodynamics and acid-base status. Because of the limited experience with long-term pneumoperitoneum, we consider invasive haemodynamic monitoring and repeat blood gas analysis essential for such operations.

Laparoscopic techniques have become a standard approach for diagnostic and therapeutic procedures in many surgical disciplines. In urology, radical prostatectomy can be performed with endoscopic techniques [1]. The computer-enhanced surgical system da Vinci (Intuitive Surgical, Mountain View, CA, USA) is a recently developed technology that allows extremely precise andatraumatic surgery by telemanipulation. The surgeon operates this system while seated at a console that allows three-dimensional visualization of the surgical field. The system translates the movements of the surgeon’s hands in the console real-time to specialized instruments positioned inside the patient through small puncture incisions. Software eliminates the tremor of the surgeon’s hands.

Like many laparoscopic procedures, this technique requires CO2 insufflation with positive pressure, to allow optimal visual-
esophageal temperature were monitored. To maintain body temperature, a heating blanket (Bair Hugger 505, Augustine Medical, Eden Prairie, MN, USA) was used. Postoperative analgesia was initiated with 7.5 mg piritramide and 1 g novaminsulfon 15 minutes before the end of surgery. After skin closure patients were either extubated in the operating room or transferred to the intensive care unit.

**Surgical Technique**

All patients were primarily in supine position. After cystoscopy and insertion of bilateral ureter stents transabdominal ports were placed and a pneumoperitoneum was created by CO2 insufflation after moving the patient into a 30-degree Trendelenburg position. While the robot is positioned right next to the patient, the system is controlled via telemanipulation by a surgeon sitting at a remote console. The surgeon’s assistant changes the instruments that are connected to the robotic arms and inserted through the ports. The operation continues with bilateral pelvic lymphadenectomy followed by immediate histological examination of the lymph nodes. After preparation and exposure of the prostate gland with consecutive urethral-vesical anastomosis, the prostate is removed via the medial port with consecutive release of the pneumoperitoneum. The operation is terminated by closure of the skin stab wounds.

**Assessment of Outcome Variables**

Arterial blood gas analysis including pH, BE, HCO3-, PaCO2, and PaO2 was performed in the operating room with an ABL3 Analyzer (Acid Base Laboratory/Hemoxymeter, Radiometer, Copenhagen, Denmark). The following data were obtained together with each blood gas analysis: minute ventilation (MV), peak inspiration pressure (PIP), intraabdominal pressure (IAP), heart rate (HR), mean arterial pressure (MAP), and central venous pressure (CVP). Baseline values were obtained prior to establishing a pneumoperitoneum with the patient in the Trendelenburg position. Further laboratory and physiological data collection was performed 10 and 30 minutes later (PP + 10, PP + 30) and at 5-minute intervals throughout the operation. Immediately after surgery with the patient still in the Trendelenburg position, a final assessment was made.

**Statistical Analysis**

All data are presented as mean ± standard deviation. Calculation and data analysis were performed using a statistical package (GraphPad InStat 3.0, GraphPad Software, San Diego, CA, USA). Statistical significance was determined with either the Friedman test and Bonferroni adjustment or the Wilcoxon-Mann-Whitney test. Differences were considered to be statistically significant if *p* was < 0.05.

**Results**

Fifteen patients with prostate cancer underwent radical prostatectomy performed endoscopically with the da Vinci telemanipulation system. Demographic and clinical data are presented in Table 1.

Total intravenous anaesthesia was adjusted to anesthesia depth levels between D0 and E1 according to Kugler [6] as monitored with the Narcotrend system (NarcoMed, Bad Bramsted, Germany). During anesthesia, patients received 5,535 ± 1,025 ml lactated Ringer's solution and 2,100 ± 625 ml hydroxethyl starch 6%. Two units of packed red blood cells were administered into a patient who received an additional 400 ml albumin 5%.

Heart rate and mean arterial pressure initially were not affected by the pneumoperitoneum. After a 4-hour pneumoperitoneum a significant increase in heart rate was observed. Mean arterial pressure remained stable during CO2 insufflation. Central venous pressure underwent only minor changes during surgery; with CO2 desufflation central venous pressure decreased and was postoperatively 24% below baseline value (*p*: n.s.) (Fig. 1a and b). Hemodynamic alterations were not of clinical relevance, and no catecholamines were required for hemodynamic stabilization. Significant ST segment changes were not observed throughout the entire operation.

During insufflation intraabdominal pressure was maintained around 12 mmHg (Fig. 1b). When CO2 insufflation was initiated, peak inspiratory pressure increased and reached significant values after a 1.5-hour period of intraabdominal CO2 insufflation. With the release of CO2, peak inspiratory pressure decreased close to baseline (*p*: n.s.) (Fig. 2a).

PaCO2 increased during the initial 90 minutes of CO2 insufflation and reached a plateau that was significantly higher than baseline and remained constant throughout the operation. Even after CO2 desufflation, PaCO2 remained significantly elevated (Fig. 3a). Minute ventilation was increased parallel to the rise of PaCO2. Even after surgery a markedly elevated MV was required to maintain pH, BE, HCO3-, and PaCO2 within physiologic ranges (Fig. 2a, 3a-d). PaO2 was not significantly affected by the pneumoperitoneum, but it decreased below baseline after CO2 desufflation (*p*: n.s.) (Fig. 2b).

Body temperature dropped 0.07°C during initial CO2 insufflation and increased by 0.18°C per consecutive hour. Mean body temperature at the end of surgery measured 37.0°C.

Exubation was achieved immediately after the operation in seven patients, while the remaining eight were extubated 40 to 545 minutes later in the ICU (median: 400 minutes).

**Discussion**

Minimally invasive surgery has seen tremendous growth after the first laparoscopic cholecystectomy was performed by Philippe Mouret in 1988. First reports on a laparoscopic radical prostatectomy were published in 1992 [1] and were followed by growing experience with this technique to treat carcinoma [7-9]. Recent progress in endoscopic surgery is based on the integration of computer-enhanced telemanipulation systems such as the daVinci technology employed in the present study. The visualization sys-

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Results are mean values ± SD.