

Intraoperative Hypercapnia and Atrioventricular Block in a Robot-Assisted Renal Transplant: A Case Report

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ABSTRACT

Robot-Assisted Kidney Transplantation (RAKT) is a minimally invasive alternative to open surgery, offering several benefits but posing anesthetic challenges related to pneumoperitoneum and patient positioning. These factors can compromise cardiorespiratory function and electrolyte balance. This case report discusses the anesthetic management of the first RAKT at the Philippine General Hospital, emphasizing the detection and treatment of intraoperative hypercapnia—an infrequent yet potentially serious complication that may result in acidosis, hyperkalemia, and arrhythmia.

Introduction

Renal transplantation remains the gold standard treatment for end-stage renal disease (ESRD) with superior survival outcomes. RAKT integrates the advantages of minimally invasive surgery with significant reduction in postoperative pain, hospital stay and enhanced precision provided by robotic technology [1].

Critical concerns during robotic surgery involve physiological effects of pneumoperitoneum and patient positioning, fluid management, and cardiopulmonary compromise [2-3]. This case report highlights a patient who developed intraoperative hypercapnia, resulting in hyperkalemia and subsequent arrhythmia during robot-assisted kidney transplantation.

Case Report

The patient is a 39-year-old Filipino male with a 7-year history of ESRD secondary to chronic glomerulonephritis

maintained on hemodialysis three times weekly. A renal transplant was suggested in 2017 but was not performed due to financial limitations. The patient was classified as American Society of Anesthesiology Physical Status Class III due to multiple comorbidities of ESRD, chronic hepatitis B, hypertension, dyslipidemia, chronic coronary syndrome, and heart failure with an improved ejection fraction (64%).

Preoperative risk assessment using the Revised Cardiac Risk Index indicated a 15.0% risk (4 points) for a major cardiac event and intermediate risk (38 points: 13.3%) for in-hospital post-op pulmonary complications on the Assess Respiratory Risk in Surgical Patients in Catalonia. Body mass index was normal (19.1 kg/m²) with a weight of 52 kilograms and a height of 165 centimeters. The patient had essentially unremarkable systemic findings, a well-functioning left arteriovenous fistula, a normal airway (Mallampati grade I), and no gross abnormalities on the back.

Hemodialysis was conducted one day prior to surgery. Preoperative laboratory investigations revealed anemia, with a hemoglobin level of 108 g/L (normal: 135–180) and hematocrit of 34% (normal: 40–54).

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Thrombocytopenia was also noted, with a platelet count of $91 \times 10^9/L$ (normal: 150–450). Serum chemistry results showed normal levels of sodium, potassium, calcium, phosphorus, and albumin. Notable abnormalities included hypermagnesemia (magnesium: 1.17 mmol/L; normal: 0.70–1.00), a markedly elevated serum creatinine level of 1138 $\mu\text{mol/L}$ (normal: 46–92), and a severely reduced estimated glomerular filtration rate (eGFR) of 5 mL/min (normal: >90). Chest radiography demonstrated cardiomegaly and atherosclerotic changes in the aorta. Transthoracic echocardiography revealed a preserved left ventricular ejection fraction of 64%, concentric left ventricular hypertrophy, and Grade II diastolic dysfunction with elevated filling pressures.

The patient was hypertensive (BP 150/80 mmHg) with heart rate (HR) 77 beats/minute, respiratory rate (RR)

19 breaths/minute, and oxygen saturation (SpO_2) 99% on room air. The ECG showed sinus rhythm. Oxygen was given at 6 liters/minute via face mask. Anesthesia induction was initiated with incremental intravenous doses of midazolam (0.03 mg/kg) and fentanyl

(2 mcg/kg). The patient was placed in a left lateral decubitus position, under strict aseptic technique. After local lidocaine infiltration, an 18G epidural catheter was placed at T12-L1 with confirmed loss of resistance and a negative test dose. General anesthesia was induced with intravenous fentanyl (3 mcg/kg), propofol (4 mg/kg), and rocuronium (1 mg/kg). Intubation was performed via video laryngoscope using an 8.0 mm armored tube, level 22. Ventilation was pressure-controlled (PCV) with pressure control of 22–25 cm H₂O, peak airway pressure (Ppeak) of 14 mmHg, positive end-expiratory pressure (PEEP) of 5 cm H₂O, tidal volume (VT) reaching

6–7 mL/kg, and RR of 16 bpm. Bilateral clear and equal breath sounds were confirmed with appropriate capnographic waveforms and end-tidal carbon dioxide (EtCO_2) 34–35 mmHg. A nasogastric tube and a right internal jugular catheter were inserted. An egg crate mattress was positioned, and the pressure points as well as the facial area were cushioned to prevent injury (Figure 1). Fluid management was monitored using an infusion pump and guided by pulse pressure variation via arterial catheter.

The patient was positioned in steep Trendelenburg (30 to 45 degrees) (Figure 2), which progressed for 4 hours without notable intraoperative complications. PCV was maintained, with a Ppeak of 22 mmHg, a PEEP of 5 cm H₂O, and VT 6–8 mL/kg at RR of 16 bpm. Intraoperative EtCO_2 levels ranged between 30 and 39 mmHg (normal: 35–45). Neuromuscular blockade was maintained with Train-of-Four (TOF)-guided rocuronium.

During wound closure in the supine position, the patient developed bradycardia (HR 30–40 bpm) with atrioventricular block. Incremental doses of atropine up to 2 mg and ephedrine (50 mg) were administered to

manage the episode with no noted improvement. Point-of-care testing (POCT) revealed acute respiratory acidosis with partial metabolic compensation: pH 7.10 (normal 7.35–7.45), partial pressure of carbon dioxide (PaCO_2) 60.1 mmHg (normal 35–45), partial pressure of oxygen (PaO_2) 73 mmHg (normal 80–100), serum bicarbonate (HCO_3) 21.3 mmol/L (normal 22–26), and base excess: -7.7 mEq/L (normal -2 to +2).



Figure 1- Robotic arms positioned with the patient placed in a steep Trendelenburg angle of 30 to 45 degrees.



Figure 2- A protective pad was placed on the patient's face, and an egg crate mattress was utilized to minimize the risk of intraoperative injury.

Significant hyperkalemia was noted with a potassium level of 7.6 mmol/L, anemia with a hemoglobin concentration of 101 g/L and hematocrit of 30%, and markedly elevated serum creatinine at 659.6 μ mol/L. Hyperglycemia was observed with a blood glucose level of 162 mg/dL (normal: 70–100), along with a mildly elevated lactate level of 1.52 mmol/L (normal:

<1.0 mmol/L). Subcutaneous emphysema was ruled out as a cause of hypercapnia due to clear breath sounds and absence of cervicothoracic crepitus. The carbon dioxide absorbent was replaced, and therapeutic interventions included administration of one vial of 50% dextrose solution (D50), 10 units of insulin, six puffs of salbutamol, and 1 gram of calcium gluconate. Hyperventilation was facilitated by increasing the RR to 25 bpm. Serial point-of-care testing was performed, revealing persistence of acute respiratory acidosis with partial metabolic compensation: pH 7.15, PaCO₂

62.5 mmHg, pO₂ 167.7 mmHg, bicarbonate

21.9 mmol/L, and base excess -7.5. Repeat POCT demonstrated metabolic acidosis without adequate respiratory compensation: pH 7.28, PaCO₂ 40.3 mmHg, pO₂ 166.7 mmHg, bicarbonate 19.2 mmol/L, and base excess -7.0. Potassium notably decreased to 5.3 mmol/L. Six units of insulin were administered, and neuromuscular blockade was reversed using sugammadex (4 mg/kg) under TOF monitoring. The patient was extubated while fully conscious, maintaining stable vital signs (BP 150/80 mmHg, HR 87 bpm,

RR 20 bpm, SpO₂ 100%) with sinus rhythm. The fluid balance was positive at +350 mL with a total fluid input of 1500 mL of crystalloids and 200 mL of mannitol and an output comprising an estimated blood loss of 100 mL, urine output of 400 mL (1.45 mL/kg/hr), and insensible losses of 850 mL (4 mL/kg/hr).

Outcome and follow-up

The patient was transferred to his room and connected to a cardiac monitor, which showed a BP of 140/80 mmHg, HR between 50 and 60 bpm, RR of 18 bpm, and SpO₂ 100% on room air, with satisfactory pain control at the time of transfer. Sinus arrhythmia with premature atrial contractions was observed, prompting referrals to cardiology and nephrology. A hyperkalemia treatment regimen was continued, consisting of a slow intravenous push of 10 mL of 10% calcium gluconate diluted with

5 mL of sterile water, three doses of salbutamol nebulization, and a gastrointestinal solution containing 10 units of human regular insulin mixed with 50 mL of 50% dextrose (D50), resulting in a post-correction potassium level of 4.8 mmol/L. A postoperative chest

x-ray and 12-lead ECG were requested, revealing a sinus rhythm with a normal axis. He was then discharged well on the sixth hospital day.

Discussion

Open kidney transplantation remains the standard treatment for ESRD, though minimally invasive options like laparoscopic and robot-assisted techniques are effective alternatives. Robot-assisted surgery offers several benefits, such as smaller incisions, reduced infection risk, minimized blood loss, less postoperative pain, and shorter hospitalization [2].

Anesthetic management of RAKT must address challenges from pneumoperitoneum and a steep Trendelenburg position, requiring multiple interventions to ensure hemodynamic stability and optimal respiratory function. These may result in decreased functional residual capacity and lung compliance, increased risk of atelectasis, elevated airway pressures, and reduced minute ventilation, potentially leading to hypoxemia and hypercapnia [3-4]. For this case, a lung-protective strategy using pressure-controlled ventilation with VT 6–8 mL/kg and a minimum PEEP of 5 cm H₂O was utilized to optimize respiratory mechanics and minimize postoperative pulmonary complications [5-6].

PaCO₂, the gold standard for assessing hypercapnia, refers to the measurement of carbon dioxide (CO₂) levels in the blood and reflects the efficiency of its removal through the lungs [7]. An elevated PaCO₂-EtCO₂ gradient suggests a ventilation-perfusion (V/Q) mismatch, where alveolar ventilation is not adequately matched by pulmonary perfusion. This discrepancy may result from several clinical conditions that interfere with the matching of ventilation and perfusion in the lungs due to prolonged steep Trendelenburg position and pneumoperitoneum [8] or from inaccuracies in measurement caused by uncalibrated equipment, such as in this case. The typical PaCO₂-EtCO₂ gradient ranges from 2 to 5 mmHg, with PaCO₂ generally being higher due to alveolar dead space [9].

Elevated levels of CO₂ in the blood are associated with a corresponding rise in serum potassium, reflecting a proportional relationship. Specifically, for every 10 mmHg increase in PaCO₂ above baseline, serum potassium may rise by approximately 0.2 mmol/L [10]. Hypercapnia resulting in acidosis promotes a shift of potassium ions from the intracellular to the extracellular space [11], contributing to hyperkalemia, which generally leads to a progressive reduction in the excitability and conduction speed of pacemaker cells and the cardiac conduction system [12]. While this commonly causes ECG abnormalities, advanced AV blocks are typically seen in patients with underlying heart conditions such as heart failure, which is present in our patient. In these cases, elevated potassium worsens pre-existing damage to the AV node or His-Purkinje system [13].

Hyperventilation was initiated for hypercapnia [14], and for hyperkalemia, salbutamol and intravenous insulin

were given to facilitate the intracellular shift of potassium. Insulin is administered with dextrose to prevent hypoglycemia. Additionally, calcium gluconate was given to stabilize the cardiac membrane and decrease the risk of cardiac complications [4, 15].

Conclusion

Robot-assisted kidney transplantation (RAKT) offers a minimally invasive alternative to open surgery with benefits like reduced pain, blood loss, and shorter hospital stays. However, anesthetic management is complex due to the effects of pneumoperitoneum and steep Trendelenburg positioning, which can impair respiratory function and lead to hypercapnia. This, in turn, may contribute to hyperkalemia—a serious postoperative risk, especially in patients with pre-existing cardiac conditions. Careful intraoperative monitoring of ventilation and electrolytes is essential to ensure patient safety during RAKT.

Ethics approval and consent to participate

Written informed consent was obtained from the patient for this case report.

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