**Introduction**

Minimally invasive techniques are becoming more and more established in cardiac surgery. Aortic valve surgery lends itself particularly well to such procedures. Mini-sternotomy and anterior right thoracotomy (ART) are two such approaches used in our institution. Such techniques are not without potential hazards, however. We report a rare case of inadvertent rhabdomyolysis and compartment syndrome in a bodybuilder undergoing minimally invasive cardiac surgery. The presentation, differential diagnoses, and management are discussed. Hyperkalemia may be the first presenting sign. Early recognition and management are essential to prevent life-threatening complications.

**Case Report**

A 29-year-old, fit and healthy professional bodybuilder presented for tissue aortic valve surgery through ART for severe aortic regurgitation, secondary to congenital bicuspid aortic valve. His medical history included regular use of anabolic steroids for bodybuilding (testosterone, nandrolone, trenbolone, and fluoxymesterone). His only prescribed medication was omeprazole. Weight was 121 kg, height was 183 cm, and body surface area was 2.48 m². Baseline serum potassium and creatinine concentrations were 4.9 mmol/l and 79 µmol/l, respectively. The patient chose to have a tissue valve to pursue his bodybuilding lifestyle and avoid anticoagulation, needed with a mechanical valve.

Anesthesia was induced and maintained with target-controlled infusions of propofol and remifentanil and rocuronium muscle relaxation. Hydrocortisone 100 mg was administered for steroid supplementation. The patient was positioned in the supine position with a gel wedge under the right shoulder, used to gain access for ascending aorta cross-clamping. The first intraoperative potassium concentration was 5.36 mmol/l on arterial blood gas (ABG) analysis.

After approximately 1 h, 45,000 units of heparin was administered to achieve an activated clotting time of 480 s and the femoral vessels were cannulated. At this time, ABG showed a serum potassium concentration of 7.36 mmol/l. The heart rate was 80 beats/min in sinus rhythm with narrow electrocardiogram (ECG) complexes and blood pressure was 100/45 mmHg. Femoral–femoral cardiopulmonary bypass (CPB) was initiated and a full flow of 5.95 l/min was achieved for the duration of CPB (130 min). Anterograde cardioplegia was given into the aortic root and then sequentially into two coronary ostia. Serum potassium concentration peaked at 7.68 mmol/l while on bypass and then showed a gradual downward trend with no significant metabolic acidosis [Figure 1].

**Abstract**

Rhabdomyolysis is the result of skeletal muscle tissue injury and is characterized by elevated creatine kinase levels, muscle pain, and myoglobinuria. It is caused by crush injuries, hyperthermia, drugs, toxins, and abnormal metabolic states. This is often difficult to diagnose perioperatively and can result in renal failure and compartment syndrome if not promptly treated. We report a rare case of inadvertent rhabdomyolysis and compartment syndrome in a bodybuilder undergoing minimally invasive cardiac surgery. The presentation, differential diagnoses, and management are discussed. Hyperkalemia may be the first presenting sign. Early recognition and management are essential to prevent life-threatening complications.

**Keywords:** Cardiac surgery, compartment syndrome, minimally invasive, rhabdomyolysis

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**How to cite this article:** Baxter SJ, Puchakayala MR, Bapat VN. Rhabdomyolysis and compartment syndrome in a bodybuilder undergoing minimally invasive cardiac surgery. Ann Card Anaesth 2017;20:453-5.
No diuretics or hemofiltration was used during CPB. The patient was separated from CPB in sinus rhythm with the aid of calcium (0.5 g) and milrinone (2 mg) boluses. At this stage, ABG showed normal acid-base function (pH 7.39), base excess −1.6, and potassium 7.07 mmol/l. No further inotropic support was required. Insulin was not used to treat hyperkalemia as there were no ECG disturbances and the patient remained in normal sinus rhythm. Autologous cell saver blood was transfused and no other blood products were used. Serum lactate concentration peaked at 4.04 mmol/l toward the end of surgery.

At the end of the surgery, the patient was transferred to the Intensive Care Unit (ICU). The peak postoperative serum potassium was 6.1 mmol/l and the peak serum creatinine was 169 µmol/l [Table 1]. There was no evidence of myoglobinuria or fever during the perioperative phase. The patient was weaned from mechanical ventilation and the trachea was extubated around 10 h post surgery. Insulin and dextrose infusions were used to maintain normokalemia in the ICU when the potassium levels increased to 6 mmol/l. The patient was polyuric and adequate fluid resuscitation ensured appropriate fluid balance. Acid-base balance remained normal. After 18 h, serum creatinine decreased to 115 µmol/l and the creatine kinase (CK) concentration was 7604 IU/l [Table 1].

On the 3rd postoperative day, the patient developed signs of shoulder compartment syndrome, characterized by severe bilateral shoulder pain, worse on the right side, and limited shoulder movement. Ultrasound and computerized tomography scans revealed bilateral edema of the supraspinatus muscle (worse on the right), with associated local compartment syndrome of the supraspinatus fossa.

Treatment was conservative with observation and patient-controlled morphine analgesia. By the time of hospital discharge on day 5, there had been improvement in the shoulder pain and mobility, his serum creatinine concentration had returned to baseline, and the CK concentration had fallen to 3535 IU/l [Table 1].

The patient was reviewed in the outpatient clinic 2 weeks post discharge. Normal shoulder mobility was seen and the CK concentration had decreased to 337 IU/l. Within 3 months, the patient resumed bodybuilding.

**Discussion**

Our patient developed rhabdomyolysis and compartment syndrome of the supraspinatus muscle. We believe that this is the first case reported in a patient undergoing minimally invasive cardiac surgery. Previous reports of compartment syndrome in cardiac surgery relate to lower leg compartment syndrome, following saphenous vein harvesting for coronary artery bypass grafting.[1]

During aortic valve replacement through the ART approach, the aortic valve is approached through a 5–7 cm incision in the second, right intercostal space, lateral to the sternum. The aortic cross-clamp is introduced through a separate 1 cm incision in the second intercostal space in the anterior axillary line. A gel wedge is used under the right shoulder to facilitate this step as it drops the arm downward in relation to the body. This could have resulted in localized external pressure. Furthermore, tissue edema occurs during CPB. In a bodybuilder, a large muscle mass may be more prone to compartment syndrome due to limited available space to accommodate this edema. As a bodybuilder, our patient was regularly using four different anabolic steroids to increase muscle bulk and performance. This increase in muscle bulk around the shoulders may have rendered our patient more susceptible to pressure-induced rhabdomyolysis and compartment syndrome during prolonged surgery.

Our case presented initially as hyperkalemia that was seen incidentally with routine ABG after heparinization. Heparin-induced hyperkalemia caused by adrenal suppression was unlikely as it takes a few hours to develop.[2] Other causes of intraoperative hyperkalemia include propofol infusion syndrome (also unlikely due to time of presentation), malignant hyperthermia, and hemolysis from massive blood transfusion.[3] It may be argued that we should have treated high potassium levels; however, the patient was in sinus rhythm without ECG changes suggestive of hyperkalemia and remained hemodynamically stable. In addition, the potassium levels decreased toward the end of surgery. Rhabdomyolysis was confirmed by high CK levels in our case. Clinical

![Figure 1: Graph showing serum potassium (K⁺) concentration and base excess on the day of surgery](image)

**Table 1: Perioperative changes in potassium, creatinine, and creatine kinase concentrations**

| Day          | −12 (baseline) | 0 (+2 h) | 1 | 2 | 3 | 4 | 5 |
|--------------|----------------|----------|---|---|---|---|---|
| K⁺ (mmol/L)  | 4.9            | 6.1      | 5.2 | 5.1 | 4.0 | 4.3 |
| Creatinine   | 79             | 169      | 115 | 117 | 98  | 78 |
| CK (IU/L)    | 2459           | 7604     | 7177 | 3535 |

K⁺: Potassium, CK: Creatine kinase
and radiographic findings confirmed supraspinatus fossa compartment syndrome later in the ICU.

A low threshold of suspicion for rhabdomyolysis is vital in aiding prompt diagnosis and treatment. Hyperkalemia may often be the first presenting sign, particularly in sedated patients. Other causes include crush injuries, hyperthermia, drugs, toxins, and abnormal metabolic states. Pressure-induced compartment syndrome, involving the back and gluteal muscles, has been reported in obese patients undergoing bariatric surgery. In rhabdomyolysis, CK levels tend to increase in the first 12 h after the skeletal muscle injury, peak by the 3rd day, then decrease by the 5th day. A CK concentration in excess of 5000 IU/l is generally associated with renal failure. Early recognition and treatment with aggressive fluid resuscitation are essential to prevent renal dysfunction. Our patient improved with conservative management including intravenous fluid therapy and only had a transient rise in serum creatinine.

If rhabdomyolysis does occur during cardiac surgery, the implications of treatment strategies must be carefully considered. Liberal fluid therapy has to be targeted to prevent ventricular dysfunction post-CPB. There is less evidence to support other strategies such as urinary alkalinization or diuretic therapy. Other preventative strategies that can be employed include using higher CPB flows and pressures in high-risk patients to improve skeletal muscle blood flow. We achieved full bypass flows though occasionally this can be difficult during minimally invasive cardiac surgery. In future, additional care should be taken with adequate positioning. A high index of suspicion is the key to early diagnosis and management.

**Declaration of patient consent**

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

**Financial support and sponsorship**

Nil.

**Conflicts of interest**

There are no conflicts of interest.

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