CASE REPORT
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Upper limb replantation: surgical strategy and the prophylaxis of acute renal failure due to ischemia reperfusion injury – A report of two cases

Replantacija ruke: hirurška strategija i profilaksa akutne bubrežne slabosti usled ishemijskog reperfuzionog oštećenja

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Abstract

Introduction. The arm replantation is an extremely rare and challenging procedure. The recognized risk is myoglobinuria and, consenquently, ischemia reperfusion-induced renal failure. **Case report.** We presented two patients aged 24 and 46 years who were admitted after traumatic arm amputation. Ischemia time was six and two hours, respectively. Postoperative intensive care treatment with assisted ventilation, sedation, and obtaining sufficient urine output prevented myoglobin-induced renal injury. In the case where ischemia time was shorter, there was only one delayed reconstruction of skin defects after fasciotomy, but in the case where ischemia lasted longer, the patient had two secondary look procedures with acceptable definitive results. **Conclusion.** Arm replantation is a safe procedure even in cases with longer ischemia time. Postoperative control of urine output, correction of acidosis, and preventing myoglobin-induced tubular injury are crucial for stable postoperative recovery and.

Key words:
hand; intensive care units; reconstructive surgical procedures; replantation; respiration, artificial.

Apstrakt

Uvod. Replantacija ruke je izuzetno retka i izazovna procedura. Jedna od komplikacija ove intervencije je mioglobinurija i posledična bubrežna insuficijencija izazvana ishemijsko reperfuzionim oštećenjem. **Prikaz bolesnika.** Prikazana su dva bolesnika starosti 24 i 46 godina, primljena nakon amputacije ruke izazvane traumom. Vreme ishemije iznosilo je šest, odnosno dva sata. Postoperativni tretman i intenzivna nega primenom asistirane ventilacije, sedacije i postizanja optimalne diureze sprečili su bubrežnu slabost izazvanu mioglobinom. U slučaju kada je vreme ishemije bilo kraće, urađena je samo jedna odložena rekonstrukcija defekata kože nakon fasciotomije, a u slučaju kada je ishemija trajala duže, bolesnik je imao dva sekundarna postupka sa prihvatljivim konačnim rezultatima. **Zaključak.** Replantacija ruke je siguran postupak čak i u slučajevima u kojima je vreme ishemije trajalo duže. Postoperativna kontrola diureze, korekcija acidoze i sprečavanje mioglobinom izazvane tubularne nekroze bubrega su presudne za stabilan postoperativni oporavak.

Ključne reči:
ruka; intenzivna nega, odeljenja; hirurgija, rekonstruktivna, procedure; replantacija; disanje, mehaničko.

Introduction

Reconstruction of upper extremity injuries is challenging, especially after traumatic amputation. There is a lack of knowledge about the impact of ischemia duration on the development of possible complications, such as myoglobinuria and acute renal failure.

Rhabdomyolysis is a clinical syndrome characterized by acute damage to the sarcolemma of the skeletal muscle leading to the release in the circulation of myoglobin,

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creatine kinase (CK), alanine aminotransferase (ALT), aspartate aminotransferase (AST), etc. [1].

During rhabdomyolysis, necroptosis and ferroptosis occur in the form of non-apoptotic cell death resulting in the accumulation of reactive oxygen species (ROS) [2], which could lead to skeletal muscle cell death [3]. Due to the toxic effects of free radicals, tubular necrosis occurs, resulting in acute renal failure [4]. We presented two patients with upper limb replantation pointing out the significance of the intensive therapy after replantation in order to prevent ischemia-reperfusion injury.

Case report

Case 1

A 46-year-old male patient was admitted with traumatic amputation of the right upper extremity that happened one hour prior to admission. The injury was caused by a wood cutting machine.

The patient underwent emergency surgery, and revascularization was achieved after two hours from injury time. External skeletal fixation was applied, followed by debridement of the wound edges, arterial and venous anastomosis by the technique of running suture. Immediately after the creation of vascular anastomoses, a heparin single dose of 10,000 I.U. was administered. Neurorrhaphy of median, radial, and ulnar nerves and musculography were performed. The skin was closed with interrupted stitches. Longitudinal fasciotomies were performed on the forearm. During surgery, the blood transfusion started with an overall amount of 1,400 mL of red blood cells (RBC) and 1,100 mL of fresh frozen plasma.

During the first two days in the Intensive Care Unit (ICU), the patient was intubated on bilevel positive airway pressure (BiPAP) ventilation mode, using midazolam sedation. The values of fraction of inspired oxygen (FiO_2), pH, and base excess (BE) in the blood are shown in Table 1. The renal excretory function was controlled by monitoring hourly diuresis that was reaching 200 mL/h in the first two days. Muscle damage was controlled through myoglobin and CK concentrations (Figures 1 and 2). C-reactive protein (CRP) reached its peak on the fourth day, measuring 164 mg/L (the normal range is < 5 mg/L) (Table 2). The high doses of bicarbonate were used for the correction of negative blood BE. Daily urine output was sufficient during recovery.

Table 1

Values of FiO_2, pH, and BE in the Case 1

Post-admission day	Time	FiO_2	pH	BE
1	21 h	100	7.225	-7.2
2	2 h	60	7.222	-7.5
2	12 h	50	7.258	-7.4
2	19 h	50	7.381	-1.4
3	7 h	21	7.400	-0.7
3	12 h	21	7.339	0.3
3	18 h	21	7.378	2.7

FiO_2 – fraction of inspired oxygen; BE – base excess.

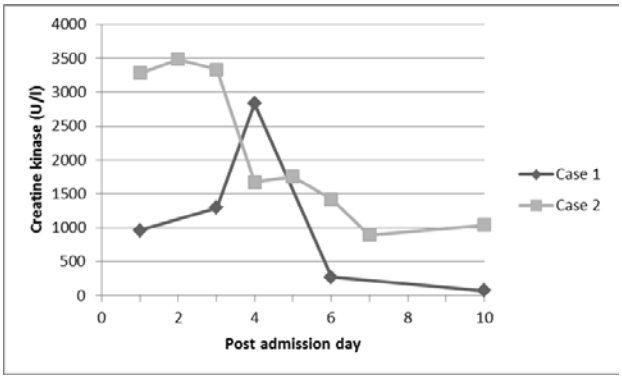


Fig. 1 – Serum creatine kinase (CK) values in the Case 1 and Case 2.

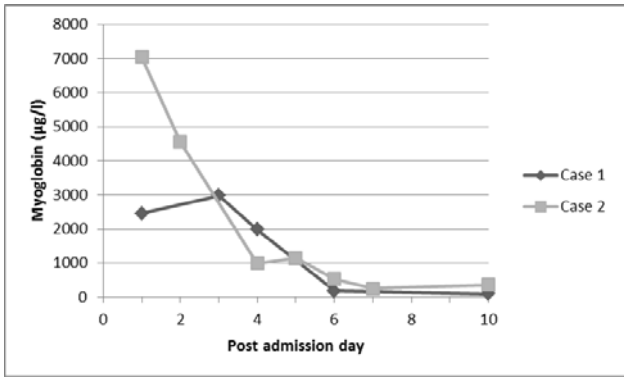


Fig. 2 – Serum myoglobin levels in the Case 1 and Case 2.

Table 2

Values of white blood cells (WBC) and C-reactive protein (CRP) in the Case 1

Post-admission day	WBC ($\times 10^9$/L) (ref ≤ 9.0)	CRP (mg/L) (ref ≤ 5)
1	11.5	6.6
3	13.7	117.4
4	9.0	164.0
6	8.9	30.4
10	7.7	15.3

The parameters of the renal function were in normal reference values at all times. On the fifth day, a second look procedure and additional debridement on the distal wound edge were performed. After that, the wound was closed. The second surgery was performed on the fifteenth day when skin defects at the site of fasciotomy were skin grafted. The patient was discharged on the twenty-seventh day.

Case 2

A 24-year-old male patient was admitted after traumatic amputation of a right upper extremity, accompanied by fractures of the lower jaw, left clavicle, and left fibula that happened four hours before admission. The injury was caused when a huge rock from the ceiling in a mining shaft fell on the patient. Revascularization was achieved one and a half hours after admission, but the total ischemia time was six hours. Debridement of devitalized bone tissue was made proximally and distally cc 2.5 cm in length converting irregular fracture lines into a sharp cut and obtaining bone fragments covered by the periosteum. All steps of surgery were the same as in the Case 1 but after performing an arterial anastomosis, bleeding from the brachial vein was uncontrolled for 20 seconds in order to eliminate the initial products of anaerobic metabolism, as well as reactive oxygen species (ROS). A drain was placed into the amputation line, and fasciotomies were performed. Because of an unstable double lower jaw fracture, a temporary Risdon ligature was applied. Intraoperative blood transfusion was administered in the amount of 1,700 mL of resuspended RBC and 880 mL of fresh frozen plasma.

During the first two days in ICU, the patient was on BiPAP ventilation mode with proper sedation. The values of FiO_2, pH, and BE, as well as leukocytes, CRP, AST, and ALT are shown in Tables 3–5. Diuresis was stimulated with 10% mannitol 125 mL/h during the first two days. Renal function was controlled by monitoring hourly diuresis, which was 245 mL/h in the first two days. The high doses of bicarbonate were used to correct the acid-base status. Muscle damage was monitored by myoglobin and CK concentrations (Figures 1 and 2). Anticoagulant therapy was administered intraoperatively by administering 10,000 I.U. of heparin, and low-molecular-weight heparin (LMWH) was given for ten days postoperatively. Anti-aggregation therapy was started on the seventh day by administering acetylsalicylic acid at a dose of 500 mg daily. The parameters of the renal function were in reference values all time.

Table 3

Values of FiO_2, pH, and BE in the Case 2

Post admission day	Time	FiO_2	pH	BE
1	11 h	60	7.296	-8.8
1	18 h	50	7.299	-7.5
1	22 h	50	7.322	-6.4
2	5 h	50	7.331	-5.7
2	11 h	50	7.446	-6.9
2	21 h	21	7.391	-3.3
3	21 h	21	7.384	-1.7
4	7 h	21	7.358	0

FiO_2 – fraction of inspired oxygen; BE – base excess.

Table 4

Values of white blood cells (WBC) and C-reactive protein (CRP) in the Case 2

Post-admission day	WBC ($\times 10^9$/L) (ref ≤ 9.0)	CRP (mg/L) (ref ≤ 5)
1	22.2	16
2	12	114.7
3	7.2	79.2
4	5.7	39
5	6.2	24.4
6	7.2	30
7	9.0	28.7
10	9.6	108
22	7.9	49.2

Table 5

Activity of aspartat aminotransferase (AST) and alanine aminotransferase (ALT) in the Case 2

Post-admission day	AST (U/L) (ref ≤ 37)	ALT (U/L) (ref ≤ 40)
1	111	37
2	154	47
3	184	49
4	105	42
10	103	162
22	42	54

The patient was operated for the second time on the seventh day when the lower jaw, left clavicle, and left fibula were stabilized by plates. Skin defects at the site of forearm fasciotomy were covered with a skin graft on the seventeenth day. Due to the pseudoarthrosis of the humerus after nine months, a bone graft of lyophilized bone was inserted, and the humerus was healed properly. Two years after surgery, the patient had a full range of motion in the elbow and wrist, but hand muscles were atrophic and functionless (Figure 3). The patient was not motivated for further treatment.



Fig. 3 – Upper limb replantation two years after surgery in the Case 2.

Discussion

The replanted and revascularized segments have numerous functional restrictions and need various corrective secondary procedures [5]. Therefore, prompt surgical care of the injured, with a short period of ischemia and subsequent adequate

intensive therapy and follow-up of patients, are the basic postulates of surgical strategies in preventing acute renal failure.

Rhabdomyolysis can be caused by a variety of factors, including muscular trauma after surgery [6], lower extremity exercise training [7], undifferentiated connective tissue disease [8], as well as non-traumatic muscle breakdown, including chemical [9] and biological agents [10, 11]. However, the highest incidence of rhabdomyolysis is associated with the onset of compartment syndrome in the extremity injuries. Diagnosis of rhabdomyolysis is confirmed by elevated plasma myoglobin levels and increased CK levels. The CK level usually rises within two to twelve hours of muscle injury, reaching maximum values at 24–72 hours [12].

In both presented cases, we found markable changes in serum CK and myoglobin levels after arm replantation (Figures 2 and 3).

CK activity was above 2,800 U/L (reference value up to 195 U/L) in the Case 1 and above 3,400 U/L in the Case 2. It is important to point out that the patient in the Case 2, who had multiple injuries and a longer ischemia time, had higher values of CK on the tenth day compared to those in the Case 1.

In the Case 1, the myoglobin level was up to 2,973 µg/L (reference value up to 92 µg/L) compared to the patient in the Case 2, whose myoglobin level was up to 7,035 µg/L. In our review of the literature, we found that the duration of surgery (about five and a half hours) had crucial risk factors for developing rhabdomyolysis and acute renal failure [13], but our two cases had not developed any sign of it.

The activity of AST and ALT, as markers of liver injury and a part of rhabdomyolitic laboratory disorders, were transitory elevated in the Case 2 (Table 5). Liver dysfunction molecular mechanisms have not yet been clarified. Literature data state that released proteases from injured muscles can be significant causes of liver damage [14].

Although the surgical requirement itself was more demanding, bearing in mind multiple injuries as well as a longer period of ischemia in the Case 2 compared to the Case 1, we can conclude that the rapid recovery of the patient in the Case 2 from compression syndrome was a result of prompt fasciotomy and adequate surgical care and proper therapy approach in ICU. Urgent fasciotomy in both patients improved venous and lymphatic drainage, in addition to the decompression of the subcutaneous and compartment pressure of the extremity in preventing compartment syndrome after revascularization and ischemic reperfusion tissue damage.

Leukocyte count in both patients were above the reference values for the first six days of surgery (max: 13.7×10^9/L, min: 7.7×10^9/L in the Case 1 and max: 22.2×10^9/L, min: 5.7×10^9/L in the Case 2), while moderately elevated CRP values were present for a longer period of time, whereby significantly more CRP values were present in the Case 2 (Tables 2 and 4).

Other laboratory parameters, including urea, creatinine, potassium, and calcium, as renal function assessment parameters, were within the reference values, which may be explained by rapid and good rehydration oxygenation and bicarbonate infusion in high doses. For the same reason, despite extensive destruction of muscle mass most severe complications of rhabdomyolysis-acute renal failure did not develop.

Conclusion

Arm replantation is a safe procedure even in cases with longer ischemia time. Postoperative control of urine output, correction of acidosis, and preventing myoglobin-induced tubular injury are crucial for stable postoperative recovery.

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