ISSN: 2545-2533 DOI: 10.32114/CCI.2020.3.4.35.46

CRITICAL CARE INNOVATIONS JOURNAL

Crit. Care Innov. 2020; 3(4):35-46

CASE REPORT

Lightning injury management at the Emergency Room – a case report of an unusual ground current injury during a local family fest.

Artur Szewczyk [1,2] ORCID https://orcid.org/0000-0001-6416-9321.

[1] *Military Medical Institute in Warsaw, Poland*
[2] *Independent Public Health Care Center in Mińsk Mazowiecki, Poland*

ADDRESS FOR CORRESPONDENCE:

Artur Szewczyk, MD

Military Medical Institute in Warsaw, Poland, Szaserów 128 Str., 04-141, Warsaw, Poland;

e-mail: artur.jerzy.szewczyk@gmail.com

ABSTRACT

Lightning injuries are one of the rarest types of injuries admitted to the ER. They are accompanied by a wide spectrum of symptoms with less or more dangerous evolutions. The most severe of them are rhabdomyolysis, acute kidney injury, and danger cardiac arrhythmias. Treatment of those patients is challenging for the whole personnel of the emergency ward. In this paper, we present a case of a 34-year-old male who suffered a lightning injury during a family fest organized at a public square. Over time, the patient's status was changing from almost a lack of symptoms to severe complications, including rhabdomyolysis, compartment syndrome, hyperkaliemia, and cardiac arrhythmias. The treatment process lasted for 18 days and included ER, ICU, Operating Room, and Internal Medicine Ward. In the discussion, the author analyses the diagnostic process retrospectively and is posing questions about an improvement of the methods for dealing with this kind of "unusual" cases at the ER.

KEY WORDS: lightning injury, critical care management, rhabdomyolysis, heart rhythm disorders.

INTRODUCTION

Lightning injuries are a cause of fatal accidents in 24 000 cases in the USA each year, with a total occurrence reported as 240 000 per year, with a 10% mortality [1]. In Poland, they were responsible for only 31.2 (SD=18.1) deaths in the years 2001-2006 without information about a total number of lightning injuries. This makes them one of the rarest accidents in all fatal cases reported at the Emergency Room (ER) in this country [2]. Usual victims of this type of injuries are males, 20-45 years old and the accidents mostly take place on open plains near the woods. Due to the physical properties of lightning, which are high energy transmission (about 1 gigajoule), enormous electric current of 30 000 amperes, extremely high temperature – 36 000 degrees Fahrenheit (20 000 degrees Celsius), unusual 300 million Volts of voltage and finally, the ability to generate ground current arcs (sparks) in the range up to 60 feet (16.3 meters), most injuries caused by lightning are extremely dangerous and unpredictable to manage. Depending on the type of lightning injury: direct strike (5% of cases, usually lethal), side splash (typical for standing under a tree that has been hit), contact injury (occurs when touching objects indistinct from the direct hit places, for example: touching a fence while it was hit by a lightning), and ground current (which is responsible for over a half of the cases of lightning injuries) [1], we may expect different combinations of the following injuries: electric and heat burn, heart failure, mechanical trauma including broken bones, blunt trauma, and neural disorders. A wide spectrum of them, with a division into early and late outcomes was shown in table 1.

Table 1. Early and late types of injuries and their outcomes presented in a lightning injury (own elaboration).

TYPES OF INJURIES AND THEIR OUTCOMES IN LIGHTNING INJURY DEPENDING ON THE TIME OF APPERANCE	
Early	open and closed fractures, cardiac arrest, confusion, hearing loss, seizures, thermal burns, ocular cataracts, upper airway injury, digestive tract rupture, big vessels rupture, loss of consciousness, pneumothorax, ear membrane rupture, foreign objects penetrating skin (shrapnel type) in effect of nearby blast,
Late	muscle pains and swallow, cardiac arrythmias, confusion, seizures, electrical burns, behavioral changes, loss of consciousness, keraunoparalysis, rhabdomylisys, acute renal failure, electrolyte homeostasis disturbances,

The rarity of these cases, and unpredictable symptoms evolution generate a problem of maintaining a proper therapy for these patients in the ER conditions. The aim of this report is to present an interesting case of a 34-year-old male injured by a ground current from a lightning strike during a local family fest, who presented unusual and late symptoms of lightning injury, to describe the evolution of these symptoms during the hospitalization at the ER and to discuss the crucial moments of the diagnostic process.

CASE PRESENTATION

A 34-year-old male was transported to the ER unit by a Medical Rescue Team after an undefined accident during a family fest taking place in a village located 15 km from the hospital. The hospital was a district hospital (main district city under 100 000 citizens) and consisted of the following departments: General Surgery with Traumatology, Obstetrics/Gynecology, Intensive Care Unit (ICU), Internal Medicine Ward, Cardiology, Pediatrics with Neonatology, Radiology). The main symptoms presented by the patient at the place of the accident were temporary loss of consciousness, falling down from a plastic chair he was sitting on and sliding about 1.5 m on his back on the ground. The situation took place almost simultaneously to the direct lightning hitting a nearby parked car. The vehicle reported some problems with electricity and its wheels have gone flat with an audible explosion. After this situation, the rescuers present at the place of the accident qualified the man as potentially injured and transported him to the abovementioned ER.

At the ER, the patient was examined by a doctor. The patient did not report any complaints except funny feelings in his calves which had burnt hair on their skin surface. The man also reported that the last thing he remembered before the lightning hit was that he was sitting on the chair with his legs stretched out and crossed, drinking beer with his colleagues when he heard a thunder and then, next time he opened his eyes, he was lying on the flipped chair some distance away from the place he was sitting. He said that first he was scared because he did not know what had just happened and his heart was trembling with fear. After a couple of seconds, when he looked himself over, he started to laugh trying to turn this situation into a funny story but the rescuers who at the time reached him were insisting on taking him to the hospital to what he finally agreed. During the examination, the leading doctor did not discover any abnormalities in the patient's life functions and parameters except of the mentioned hair loss on the skin of the calves. ECG showed a subtle tachycardia with sinus rhythm of about 95 beats/min and the RR was 135/80. Arterial blood

saturation, shown on pulse oximeter, was 98% without an additional external oxygen source. Venous blood sample was tested for complete blood count with smear, C- reactive protein (CRP), ionogram, glucose, creatinine, blood urea nitrogen (BUN), creatine kinase: general and with myocardial band (CK / CK-MB), lactate dehydrogenase (LDH), D-dimer, and cardiac troponin I (cTnI) which did not show any abnormalities. On the lower extremities, the skin did not present any external signs of a burn, skin lacerations or Lichtenberg's figures. Because the patient was wearing rubber-foam sandals which were wet, skin over the patient's soles also was wet, pale, and colder than the skin of the rest of the parts of his legs and it did not present any pain during the examination. Instead of normal results of blood tests and the patient feeling good, the doctor decided to keep the patient for an observation for the next 24 hours lying on the bed with a slightly raised legs and under the cardio-monitor surveillance. At first, the patient did not want to stay but after a short conversation about late outcomes of plausible lightning injury, he agreed to stay at the hospital for another six hours. The patient was administered an intravenous infusion of 500 ml 0.9% natrium chloratum.

After 6 hours, the patient reported an itching in his calves' skin and soles. The second examination revealed that the skin remained pale and cold with capillary recurrence on the feet nail plates prolonged to 5 seconds. Pain transmission and perception was symmetrical and normal. The leading doctor has decided to repeat the lab test. The second results showed an increase in white blood cells for over 12 000, unimportant decreases of red blood cells and hematocrit which were probably secondary to fluid administration, and an increase in LDH to over 500 U/l (upper reference limit (URL) 240 U/l) with no changes in the renal function and cardiac parameters. In conclusion, the patient was diagnosed as suffering from muscle damage related to ground current injury. The patient was immediately transferred to the ICU department for further observation and treatment. The patient's state at the ICU was changing within hours in the order shown below:

- **0-6 hours** after administration to the ICU:
  - Temperature increasing to 37.5°C
  - Increasing swelling of lower extremities under the knee and pain related to it
  - Continued deterioration of tissue perfusion
  - Tachycardia over 100 beats per minute

- **6-12 hours** after administration to ICU (instead of the previously mentioned symptoms):
  - Increasing LDH (>1000) and CK (> 15000) concentration
  - Blood potassium concentration elevated to over 5.6 mmol/L (URL 5.5 mmol/L) with only slightly elevated creatinine level to: 1.6 mg/dL.
  - D-dimer concentration 1 600 µg/L (URL 500)
  - Still elevating WBC (>18 000), CRP 34 mg/l (URL <5 mg/l) and fever – 38.5°C
  - Tachycardia as above with occasionally extra systolic ventriculair (ESV) in ECG with peaked T- waves
  - Swollen legs downward from the half of the tights with irregular small bruises in the area of musculus gastrocnemius.

- **12-24 hours** after administration to the ICU (instead of the previously mentioned symptoms):
  - maximal LDH (2 300) and CK (45 000) concentration
  - Blood potassium concentration: 6.1 mmol/L with creatinine level: 2.5 mg/dL, oliguria
  - D-dimer concentration 1 500 µg/L (URL 500)
  - WBC stabilized at 24 000 , CRP 99 mg/l (URL <5 mg/l) and fever – 37.5°C (after drugs and antibiotics administration)
  - Tachycardia to 130 beats/min with peaked T waves and increased QRS duration, absence of the P wave with the QRS complex becoming a sine wave
  - Swollen legs as before but with more bruises and with the ultrasound findings characteristic for rhabdomyolysis
  - Pain remaining opiates administration
  - Confusion type neural disorders
  - Increased procalcitonin (PCT) level to 2.54 ng/ml (URL 0.4)
  - Tachypnoea >18 min
  - Due to the risk of acute compartment syndrome, a fasciotomy procedure has been carried out in both legs in the musculus gastrocnemius area.
  - Intensive fluid care with catheterization of the urinary tract was performed for a better potassium draining and electrolytes balance improvement.
  - Dark urine, rich in myoglobin.

- **>24 hours** after administration to the ICU (instead of the previously mentioned symptoms):
  - Decreasing LDH (<1 500) and CK (<30 000) concentration
  - Blood potassium concentration: 6.5 mmol/L with creatinine level: 3.2 mg/dL, forced diuresis.
  - Stable D-dimer concentration 1 200 µg/L (URL 500)
  - WBC decreasing to 20 000, CRP 130 mg/l (URL <5 mg/l) temperature <37°C

- Between 24-48 hours, there were 2 observed episodes of ventricular tachycardia (VT), which was treated in the first episode with cardioversion and in the second with a betablocker with good results, finally the VT was diagnosed by a cardiologist as a Brugada sign caused by hyperkaliemia. Dialysis was performed with a very good result and no other Brugada sign episodes were observed. Potassium level after dialysis was estimated at 5.0 mmol/L.
- After fasciotomy, both legs were treated with a standard protocol for this procedure without observing further swelling. Opiates were prolonged for better pain control. Antibiotics (Cefazolin) were continued.
- Patients neurological state was stable
- PCT decreased to 1.5 ng/ml

Total patient treatment at the ICU lasted for 4 days. Next, he was transmitted to Internal Medicine Ward with everyday surgical consultations. He was discharged from the hospital after a total of 18 days of hospitalization. There was no long-term follow up information about this patient.

DISCUSSION

The case described above is an example of rare but difficult situations that may occur at the ER, especially in the district and province ones. Although every doctor should know the basics of the lightning injury treatment, a lack of experience may cause situations in which at some point of the diagnostic process, early and non-specific symptoms of severe after-effects in the mentioned injuries may remain unnoticed. After a detailed analysis of the situation, the author has decided to pose questions about the described case, as shown below:

Question 1: *Was the described situation a good and typical example of this kind of injury?*

Typically, most lightning injuries are related to different types and severity of burns, most common are electrical burns but they often have a “thermal burn” component (which usually comes from burnt clothes). Differences between electrical and thermal burns are very important and also depend on the type of electricity that caused the injury. High voltage burns are severe because the damage runs its course throughout the victim’s body. Exterior injuries are misleading in this type of burns as most of the damage occurs underneath the skin with the location of the biggest damage in the subdermal tissues [3]. For these types of burns

characteristic are Lichtenberg figures [4]. Electrical arc burn occurs when electrical energy passes from a high-resistance area to a low-resistance area. As the electricity ionizes air particles to complete the circuit, no physical contact is required to induce an arc burn. The generated heat may reach 4 000 degrees Celsius. This temperature is able to vaporize metal and ignite a victim's clothing[5]. Excessed energy from the arc may dissipate in the form of an explosion [6]. In addition, a high-current arc can produce a pressure wave blast in excess of 1000 pounds per square inch of pressure. A blast of this size can throw the victim at a small distance [7].

After analyzing some facts, which were a lack of any clothes damage, wearing shoes with a rubber sole by the patient, a lack of any signs of damage on the skin of the lower extremities, including Lichtenberg figures or electric spark contact points, it was not apparent that the patient should be diagnosed as a victim of electrical burn, especially as the patient was not presenting any other symptoms characteristic for lightning injury like ruptured eardrums, ocular cataract, pneumothorax [8] or cardiac arrythmias. Taking into consideration the mentioned properties of the electrical burn, we may assume that the patient was not presenting typical electrical burn symptoms in the early phases, but due to some environmental facts, like witness reports and circumstances of the accident, electrical burn should be considered as plausible – which has been done at the ER.

Question 2: *Was it possible to prevent such severe after-effects of the injury in the earlier phase?*

To the most dangerous after-effects of the described case, we may include rhabdomyolysis with subsequent compartment syndrome, acute kidney injury (AKI), hypotension, and late cardiac arrythmia. Both AKI and arrythmia were results of increasing hyperkaliemia, related to a massive muscle tissue damage. Rhabdomyolysis may present under a variety of forms depending on the primary cause. It may be severe with massive muscle injury or minor, even subclinical, in the case of a small, superficial muscle tissue damage. The classical triad of symptoms is muscle aches, weakness, and tea-colored urine. Some more specific symptoms include muscle tenderness, swelling, cramping, stiffness, weakness, and loss of function of the relevant muscles, and they are observed in more severe cases. The most common muscle groups presenting rhabdomyolysis are postural muscles (e.g. lower back), thighs, and calves. Muscle swelling might not be apparent until after intravenous (IV) fluids rehydration which has happened in the described case.

To other, non-specific symptoms, we may include fever, malaise, abdominal pain, nausea, and vomiting. Mental status changes may occur due to the underlying cause: trauma, toxins or drugs, infections, electrolyte abnormality, or urea induced encephalopathy [9]. Most common findings during physical examination are limb induration and skin changes like blisters or discoloration, which are the result of ischemic changes in the involved tissues. However, there may be no specific signs of muscle involvement [9]. It is important to mention that rhabdomyolysis is a common manifestation of drugs, toxins, and venoms poisonings. It is related with alcohol abuse, certain types of mushroom, and snake venom. It maybe also be triggered by the serotonergic syndrome caused by administration of selective serotonin reuptake inhibitors, other antidepressants or pethidine and amphetamine-like substances [10]. The evolution of rhabdomyolysis is dynamic and unpredictable. It may stay in a subclinical state until the compensating mechanisms begin to be insufficient. This may last up to 72 hours, but usually the first outcomes appear after 2-12 hours with the peak at 24-72 (rarely 48-72) hours and a decrease in the next 8-10 days [11]. Rhabdomyolysis could be an incidental finding of a laboratory test. AKI and arrythmia are results of increasing hyperkaliemia and their severity is strictly connected with the concentration of potassium in blood. Additionally, AKI may be accelerated by the myoglobin which has a triple effect on developing an acute renal failure. Firstly, myoglobin has a direct nephrotoxic effect due to its activity as peroxidase-like enzyme [12].

Secondly, renal vasoconstriction is caused by renin-angiotensin, vasopressin, and sympathetic innervation, activated due to the depletion of intravascular volume [13]. Thirdly, myoglobin interacting with Tamm-Horsfall protein creates casts (more vigorously in an acidic environment), obstructing the tubuli, along with sloughed destroyed cells from tubular necrosis [14]. Crucial in preventing these after-effects of rhabdomyolysis is preventing further muscle tissue damage, improving renal filtration, preventing electrolyte disorders and acidosis. It is mentioned that more suitable for renal filtrations are mannitol (only if the patient does not suffer from hypotension) [15] than loop diuretics like furosemide [16]. Also, steroids may protect the patient from proceeding muscle degradation [17].

Preventing cardiac arrythmias is related with managing a stable potassium balance. Monitoring blood for early hypocalcemia may be one of the methods of preventing late arrythmias. Taking into consideration all the mentioned pathologies and prolonged subclinical outcomes, the author suggests that under normal circumstances at the ER department, for a personnel without experience with lightning injuries, it is not

possible to prevent severe, long-term after-effects, but a good interview about the exact events that have happened before and after the accident is crucial for future diagnostic process and treatment.

Question 3: *Should the patient have been admitted to the district hospital or maybe to the higher reference unit?*

Due to a lack of any severe symptoms at the place of the accident and in the early phase of the diagnostic process, there were no relevant medical indicators for transporting the patient to a hospital of higher than district reference. It would have been different if the patient had been presenting one of the other symptoms or injuries, like penetrating wounds, massive skin burns, airways and respiratory tract burns, cardiac arrest with efficient CPR or suspicious neurological symptoms (eventually changing in the further GCS examinations from mild (12-15 points) to moderate (9-12 points) or moderate to severe (3-8 points) [18]. In these situations, the author suggests that the patient should be transported directly to the hospital with a Trauma Center.

Question 4: *What in a retrospective range can/could been done more or better in the first 24 hours of the described case?*

Thinking retrospectively about medical cases always causes a lot of controversies, because in the diagnostic moment, we do not have a full image of the patient's symptoms and their evaluations. Also, there is a trend to over-diagnose patients in a retrospective analysis. Essential for the good post-treatment analysis is to remember about two things: 1. What diagnostic instruments do we have at the ER at the moment of the patient's arrival and what is the time needed to obtain first blood test results? 2. Would the revised diagnostic process be based only on the actual state and symptoms of the patient or will it be instinctively affected by the information we have from the complete diagnostic process? To prevent those situations, we should think about the diagnostic process as about "closing in on a far away object" e.g., a monument we observed from a car window during a ride. Firstly, we only see the general shape and dominant colors, but the closer we are to the object, the more details we are noticing and we may more accurately describe the colors, shapes, and structures it is made from. Retrospectively, in the presented case, the author suggests that the imaging diagnostic of the swollen muscles may have been carried out earlier, when the first evolution of symptoms

occurred on the 6th hour of hospitalization. At the same time, the blood panel should have been repeated and expanded to parameters more characteristic to renal and cardiac profile, including early monitoring of calcium, blood ferrum, magnesium, phosphate, and myoglobin. In addition, anti-swelling therapy should have been more aggressive due to the increasing pain. Lastly, the patient should have been transported to a hospital with higher reference after the detection of the first signs of potential compartment syndrome. As it was mentioned before, these are only the author's retrospective observations and they do not represent any guidelines or a diagnostic path.

Question 5: *What may we do to improve our experience in maintaining "challenging medical cases" in the future?*

The key to the improvement of our abilities to handle rare and challenging medical cases is to focus on the dynamics of the pathological processes currently presented by the patient and extending the diagnostics (both: imaging and laboratory) to be more specific to the rare conditions. To facilitate monitoring every change in the patient's status, the author suggests preparing a "patient's timeline" for internal use – with marking every test, new symptom, and administrated medicaments for a better overview of the patient's situation. An exemplary template of the patient's timeline was shown in fig. 1.

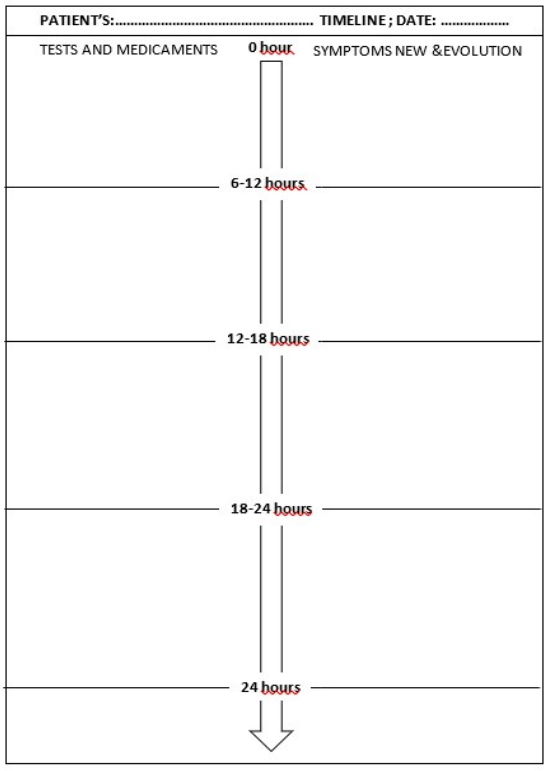

Figure 1. Patient's timeline- example (own elaboration).

Second thing, maybe even more important, is to be up to date with the current press, especially with titles related with our medical specialization. This will provide us with a ready-to-use experience from similar cases. Online databases are full of interesting and rare clinical cases and they may lead us on proper diagnostic path. Therefore, it is important to publish every challenging and unusual case in the professional press, so that other teams may benefit from our experience.

CONCLUSION

Lightning may cause serious late complications, despite the absence of clinical symptoms in the first hours after the event. To be expected: rhabdomyolysis, cramped syndrome, hyperkalemia and cardiac arrhythmia. The lack of experience of the medical personnel may cause situations in which, at a certain stage of the diagnostic process, early and non-specific symptoms of severe consequences of injuries may go unnoticed.

Disclosure statement

The authors did not report any potential conflict of interest.

REFERENCES

[1] Jensen JD, Thurman J, Vincent AL. Lightning Injuries. In: StatPearls. StatPearls Publishing, Treasure Island (FL); 2020.

[2] Pfortmueller CA, Yikun Y, Haberkern M, Wuest E, Zimmermann H, Exadaktylos AK. Injuries, sequelae, and treatment of lightning-induced injuries: 10 years of experience at a Swiss trauma center. Emerg Med Int. 2012: 167698
doi: https://doi.org/10.1155/2012/167698

[3] Docking P. Electrical burn injuries. Accid Emerg Nurs. 1999; 7(2): 70-76.
doi: https://doi.org/10.1016/s0965-2302(99)80024-1

[4] Mutter E, Langley A. Cutaneous Lichtenberg figures from lightning strike. CMAJ, 2019; 191(9): E260.
doi: https://doi.org/10.1503/cmaj.181221

[5] Furtak M. Ignition and melting characteristics of apparel fabrics. IAEI NEWS, 2015: 10-13.

[6] Brandão C, Vaz M, Brito IM, Ferreira B, Meireles R, Ramos S, et al.. Electrical burns: a retrospective analysis over a 10-year period. Ann Burns Fire Disasters. 2017; 30(4): 268–271.

[7] Wang Y, Beekman J, Hew J, Jackson S, Issler-Fisher AC, Parungao R, et al.. Burn injury: challenges and advances in burn wound healing, infection, pain and scarring. Adv Drug Deliv Rev. 2018; 123: 3-17. doi: https://doi.org/10.1016/j.addr.2017.09.018

[8] Obuchi T, Miyoshi T, Miyahara S, Hamanaka W, Nakashima H, Yanagisawa J, et al.. Does pneumothorax occurrence correlate with a change in the weather? Surg today, 2011; 41(10): 1380. doi: https://doi.org/10.1007/s00595-010-4482-y

[9] Keltz E, Khan FY, Mann G. Rhabdomyolysis. The role of diagnostic and prognostic factors. Muscles Ligaments Tendons J. 2014; 3(4): 303-312.

[10] Efstratiadis G, Voulgaridou A, Nikiforou D, Kyventidis A, Kourkouni E, Vergoulas G. Rhabdomyolysis updated. Hippokratia, 2007; 11(3): 129–137.

[11] Tietze DC, Borchers J. Exertional rhabdomyolysis in the athlete: a clinical review. Sports Health. 2014; 6(4): 336–339. doi: https://doi.org/10.1177/1941738114523544

[12] Boutaud O, Roberts II LJ. Mechanism-based therapeutic approaches to rhabdomyolysis-induced renal failure. Free Radic Biol Med. 2011; 51(5): 1062-1067. doi: https://doi.org/10.1016/j.freeradbiomed.2010.10.704

[13] Lima RSA, da Silva Junior GB, Liborio AB, Daher EDF. Acute kidney injury due to rhabdomyolysis. Saudi J Kidney Dis Transpl. 2008; 19(5): 721-729.

[14] Plotnikov EY, Chupyrkina AA, Pevzner IB, Isaev NK, Zorov DB. Myoglobin causes oxidative stress, increase of NO production and dysfunction of kidney's mitochondria. Biochim Biophys Acta. 2009; 1792(8): 796-803. doi: https://doi.org/10.1016/j.bbadis.2009.06.005

[15] Brown CV, Rhee P, Chan L, Evans K, Demetriades D, Velmahos GC. Preventing renal failure in patients with rhabdomyolysis: do bicarbonate and mannitol make a difference? J Trauma. 2004; 56(6): 1191-1196. doi: https://doi.org/10.1097/01.ta.0000130761.78627.10

[16] Karajala V, Mansour W, Kellum JA. Diuretics in acute kidney injury. Minerva Anestesiol. 2009; 75(5): 251-257.

[17] Antoon JW, Chakraborti C. Corticosteroids in the treatment of alcohol-induced rhabdomyolysis. Mayo Clin Proc. 2011; 86(10): 1005-1007. doi: https://doi.org/10.4065/mcp.2011.0102

[18] Jain S, Iverson LM. Glasgow Coma Scale. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2020