The Impending Crush Injury Syndrome During A Disaster

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ABSTRACT

The impending crush injury syndrome should be a concern when facing any severe injuries, especially disaster. Crush injury is severe shock accompanied by kidney failure. Therefore, prompt diagnosis and treatment are very critical. This paper aims to describe the impending crush injury syndrome during a disaster. This is a narrative literature review. Google Scholar, PubMed, and Science Direct were used as databases for journal findings. The selected journals were summarized and descriptively narrated. The crush injury syndrome usually occurs after severe musculoskeletal injuries and some disasters such as earthquakes, mining disasters, tornadoes, floods, explosions, etc. The injury happens when strong pressure from heavy objects hits the body. The symptoms are nerve damage, bruise, swelling, paralysis, amputation, bleeding, and death. Other common complications are renal failure and compartment syndrome. The warning symptoms are increasing pain, numbness, and tightness. The prevention of crush injury includes following safe work guidance, maintaining good housekeeping, organizing the surrounding objects to prevent any possible hazards, and being aware of heavy machines, falling objects, or vehicles. In conclusion, impending crush injury syndrome during a disaster could be prevented by prompt management and prevention.
Keywords: *crush injury syndrome, disaster, severe shock*

INTRODUCTION

The impending crush injury syndrome should be a concern when facing any severe injuries, especially disaster. Crush injury is severe shock accompanied by kidney failure. This injury happens due to the direct physical crushing of muscles by any large objects. It is also known as rhabdomyolysis. Immediate death and delayed mortality could happen due to injury of vital organs. This injury is mostly found in disasters such as earthquakes, explosions, mining disasters, cyclones, etc. The patients will have a poor prognosis (Banerjee et al., 2021; Jin et al., 2022; Rajagopalan, 2010).

Man-made disaster categories such as war, terrorism, and mining accidents could affect large numbers of crush injury patients. However, in civilian life, the causes of crush injury syndrome are usually collapse of structures during earthquakes, tsunamis, hurricanes, and land-slides. Industrial accidents and road traffic collisions can also cause crush injury syndrome. Bedridden patients for a long time due to unconscious patients after strokes or intoxication might encounter rhabdomyolysis when pressure areas are not well protected. Alcohol, animal bites (snake), toxins, and cocaine can cause crush injury syndrome. Certain types of heat stroke, burns, electrocution, seizure, and severe exercise might induce crush injury syndrome in patients with comorbidities or certain medical conditions (Jagodzinski et al., 2010)

Crush injury syndrome (sometimes also written as crush syndrome only) is a systemic response to severe crush injury. It is accompanied by hyperkalemia, deep tissue damage, and acute kidney injury. Firstly, muscle damage happens due to the direct effect of trauma (baromyopathy). After that, there is an increased intramuscular pressure. Some substances are released from crushed muscle into the systemic circulation. (Yazıcı et al., 2023)

Crush syndrome (traumatic rhabdomyolysis) causes some metabolic changes due to severe injury of the skeletal muscles. The muscle contents are further released into the

circulation. The level of creatine phosphokinase (CPK) increases five until ten times above normal (approximately 1,000 U/l). (Huq et al., 2017; Kandemir & Gul, 2023)

There was a huge earthquake in Turkey with a 7.8 magnitude on 6th February 2023. With over 40,000 deaths over the region made this earthquake the worst one ever recorded. This incident emphasized the importance of disaster management for any disaster. Depending on the magnitude of the earthquake, the incidence of acute kidney injury due to crush injury varies approximately from 0.5% to 25% of the victims. (Kandemir & Gul, 2023; Yazıcı et al., 2023)

Crush syndrome means a systemic manifestation of muscle cell injury after myocyte contents release into the blood circulation. High-energy trauma often causes crush injury syndrome. Mortality could happen because of an acute kidney injury (Banerjee et al., 2021; Jin et al., 2022). Other causes of mortality are circulatory dysfunction, severe electrolyte disorders, multiple organ failure, reperfusion injury, and severe rhabdomyolysis. (Arango-granados et al., 2020)

The symptoms of crush injury are acute respiratory distress syndrome, disseminated intravascular coagulation, hypovolemic shock, psychological trauma, and arrhythmias. Evacuation might be needed. Rescue, rehabilitation, and resuscitation have to be done to prevent any complications (Rajagopalan, 2010).

The history of crush injury syndrome begins when some victims of an earthquake in Italy in 1909, suddenly died due to renal failure. At first, they were looked in normal condition, however, rhabdomyolysis happened gradually. Traumatic rhabdomyolysis or Bywaters syndrome are other names for crush syndrome (N. Li et al., 2020).

Approximately 50% of the victims usually suffer from acute renal failure. This number is increasing by almost 100% in patients with symptoms that persist for 40 hours. The mortality rate is up to 40% if the symptoms last for more than three weeks. (W. Li et al., 2009)

Crush injury syndrome is caused by direct or indirect trauma. This trauma crushed the limbs or other muscle-rich body parts. Furthermore, the compression and degeneration of striated muscle cells take place. Nephrotoxic myoglobin, urate, phosphate, and potassium are released into the blood circulation after the blood supply has been restored. This condition causes myoglobinuria, acute kidney injury, electrolyte metabolic disorders, hypovolemic shock, and multiple organ dysfunction syndrome. The treatments are focused on early fluid resuscitation, forced diuresis, and renal replacement therapy (kidney transplantation). Although the treatment has been given, patients might have a systemic inflammatory response syndrome (SIRS), multiple organ failure (MOF), and results in death (Kodadek et al., 2022; N. Li et al., 2020). Therefore, prompt diagnosis and treatment are very critical. This paper aims to describe the impending crush injury syndrome during a disaster.

LITERATURE REVIEW

Crush syndrome might happen when a patient is buried under collapsed buildings. Acute renal failure, rhabdomyolysis, and shock are found after a short period. However, acute renal failure could be avoided if the patient is given fluid therapy and diuresis as soon as possible (Yokota, 2005). Meanwhile, a Napoleonic Army surgeon described a crush syndrome in 1812 in a comatose soldier. This soldier had muscle and skin necrosis in the pressure areas. During the First World War, German physicians recognized the crush syndrome in 1909 after the Messina earthquake (Jagodzinski et al., 2010)

The etiology of crush injury syndrome is direct trauma from physical crushing/compressive force of the muscles. Crush syndrome (traumatic rhabdomyolysis)

comprises a set of metabolic, physiological, and immunological alterations brought on by ischemia/reperfusion injury to the skeletal muscle. Muscle injury induces sarcolemma membrane destruction, cell lysis, and release of intracellular components into the systemic circulation. Therefore, the prognosis is poor (N. Li et al., 2020).

Crush injury could happen due to victims of multiple accidents such as motor vehicle accidents, earthquakes, and mining accidents. Patients who are trapped under collapsed buildings, machinery, or construction incidents, are prone to crush syndrome. Patients with prolonged immobilization which is caused by coma, surgery, or lower extremities (hip/femoral/tibial fracture), might have special risks of crush injury syndrome. Abused children, fire accidents, high-voltage electric shock, lightning, explosion, war, or bombing victims, could get severe rhabdomyolysis. Natural disasters victims such as floods, earthquakes, hurricanes/tropical cyclones, or tornadoes are prone to crush injury syndrome (Jagodzinski et al., 2010; N. Li et al., 2020).

The pathophysiology of crush injury involves muscle injury and rhabdomyolysis. Rhabdomyolysis happens due to immediate cell disruption by local forces, direct pressure/ischemia, and vascular compromise. When the main blood vessels are compressed, there will be muscle blood loss. Muscles can survive up to 4 hours without blood flow. After that, cells will begin to die. However, the period is shorter when the cause is direct trauma. Potassium, myoglobin, urate, and phosphate are released. This condition contributes to systemic signs such as myoglobinuria, hyperkalemia, hypovolemia, hypotension, lower heart rate, and lower cardiac output. (Jagodzinski et al., 2010; Torres et al., 2015)

Diagnosis of Crush Injury Syndrome is done based on a positive blood reading on urinalysis and heme-positive urine in the absence of red blood cells on microscopic examination (myoglobinuria). Creatine phosphokinase (CPK) is another marker of muscle damage because CPK is released when muscles are damaged. In rhabdomyolysis, CPK levels are very high, often above 30,000 units/liter. The higher level of CPK, the higher level of muscle damage will be. Elevated CPK levels greater than 5-10 times normal are usually considered diagnostic of rhabdomyolysis. CPK has a half-life of approximately 1.5 days and myoglobin has a half-life of approximately 3 hours. Therefore, checking CPK and myoglobin levels can help guide treatment decisions. (Esposito et al., 2018)

Renal vasoconstriction is a pathognomonic feature of rhabdomyolysis-induced acute kidney injury. Bleeding and fluid sequestration in the damaged muscle compromise the renal blood supply. Furthermore, hypovolemia activates the renin-angiotensin system. Cytokines (thromboxane A2, tumor necrosis factor α, endothelin-1, and vasodilator nitric oxide deficiency have important roles in the pathogenesis of acute kidney injury. Moreover, oxidation of iron in myoglobin, hydroxyl-radical formation, hyperphosphatemia, hyperuricemia, reperfusion injury, endotoxins, and disseminated intravascular coagulation are also associated. (Yazıcı et al., 2023) The term reperfusion injury was first stated by an American physiologist, WB Cannon. He found that a lieutenant caught in a dugout after a shell burst died 32 hours after extrication. The rapid deterioration and shock were profound after permitting the circulation to come back to the damaged tissue. (Jagodzinski et al., 2010)

Clinical findings are inflammation in the traumatized area and systemic symptoms due to the released substance from crushed muscle. Bone fracture, muscle laceration, bleeding, and contusion might be seen. Compartment syndrome is the most important finding. Patients will feel the 6 P signs of ischemia, namely pressure, pain, paresthesia, paresis, pallor, and pulselessness. The usual treatment for compartment syndrome is the fasciotomy (opening of

the fascia). Ischemia, hypoxia, edema, and necrosis are also other signs of patients with crush injury syndrome. (Jagodzinski et al., 2010; Yazıcı et al., 2023)

The recovery process takes place if the ischemia is stopped during the hypoxia and edema phase. The first 6–8 hours are the golden hours. It takes approximately 12–24 hours for an irreversible condition. Systemic findings are hypovolemic shock, acute kidney injury, hypotension, arrhythmia, respiratory failure, heart failure, sepsis, and disseminated intravascular coagulation. Oliguria and anuria are often seen in acute kidney failure patients (Yazıcı et al., 2023)

The electrolyte imbalances in crush injury syndrome patients include hyperkalemia, hyperphosphatemia, and hypocalcemia. It is associated with life-threatening arrhythmias. In this case, continuous monitoring of the ECG may be required as it may be life-threatening (Esposito et al., 2018). The differential diagnosis for Crush Injury includes acute compartment syndrome, vascular injury, bone fracture, and soft tissue injury. Acute compartment syndrome is a condition where pressure within the muscle compartments increases. Symptoms include pain, swelling, and decreased sensation. (Ferla et al., 2018)

METHODOLOGY & DATA

This is a narrative literature review. Google Scholar, PubMed, and Science Direct were used as databases for journal findings. The selected journals were summarized and descriptively narrated. Inclusion criteria are the articles that were published within 20 years. Keywords for searching the journals are crush injury syndrome, disaster, management, prevention, and earthquake. Finally, there were 17 articles selected, which were published from 2005-2023. A long range of publication time (i.e. 20 years) was selected because the time of tremendous earthquakes and other disasters varies.

DISCUSSION

The crush injury syndrome usually occurs after severe musculoskeletal injuries and some disasters such as earthquakes, mining disasters, tornadoes, floods, explosions, etc. The injury happens when strong pressure from heavy objects hits the body. The symptoms are nerve damage, bruise, swelling, paralysis, amputation, bleeding, and death. Other common complications are renal failure and compartment syndrome. The warning symptoms are increasing pain, numbness, and tightness. The prevention of crush injury includes following safe work guidance, maintaining good housekeeping, organizing the surrounding objects to prevent any possible hazards, and being aware of heavy machines, falling objects, or vehicles. (Jin et al., 2022).

Acute renal failure is usually the cause of mortality in crush injury syndrome patients. Ischemic Post-conditioning (IPC) might be useful in the protection of ischemic reperfusion injury. IPC would become a time-saving method to prevent crush-induced Acute Kidney Injury by decreasing the release of nephrotoxic substances (Huq et al., 2017; Jin et al., 2022).

Intensive care, hemodialysis, infection control, and prevention of compartment syndrome are some preventions to reduce the risks of mortality. However, the practice would be difficult, because there are usually many casualties during a disaster. The possibility of crush injury syndrome should be well predicted during patient triage and transportation (Yokota, 2005). Patient's age is an important factor to be considered when handling patients with trauma, especially the elderly. In the elderly, the mortality rate is six times greater than in younger patients with the same trauma condition. (Dimitriou et al., 2011). Children are also at increased risk of death compared with adults in crush injuries. (Belli et al., 2020)

Aggressive fluid replacement without any potassium content is given as soon as possible to prevent hypovolemia and increase urinary flow. Alkalinization of the urine pH might reduce the risk of tubular cast formation and hyperkalemia. Hyperkalemia is one of the death causes of the patient due to its relation to cardiac arrhythmia. However, extremity amputation should not be done only to prevent the crush syndrome, except if there is a severe inflammation/infection. (Kandemir & Gul, 2023; Kodadek et al., 2022)

Intermittent hemodialysis might be required because crush injury syndrome patients are prone to hyperkalemia and fatal arrhythmias. Sterile replacement fluid in a large amount can be difficult to obtain in a disaster when dealing with dialysis patients. Continuous renal replacement therapy could be a choice for acute kidney failure patients. (Kodadek et al., 2022)

Prompt treatment and monitoring of the complications are critical in saving patients' lives during the management of crush injury syndrome. A well-equipped front-line ICU close to the epicenter of the disaster location (for example earthquake) is essential for rescue procedures. It will decrease complications, amputation, and mortality rates. Sufficient equipment has to be prepared to meet the requirement of more patients. (W. Li et al., 2009) Disasters such as earthquakes and other mass accidents, demand preparation of local health-care systems such as ventilators, dialysis machines, and intensive care units. (Yazıcı et al., 2023)

CONCLUSION

In conclusion, impending crush injury syndrome during a disaster could be prevented by prompt management and prevention. The prevention could be from two factors, namely environment and the therapy of the patients. The prevention of crush injury from environmental factors includes following safe work guidance, maintaining good housekeeping, organizing the surrounding objects to prevent any possible hazards, and being aware of heavy machines, falling objects, or vehicles. Meanwhile, from the patient management, it is important to prevent any acute renal failure and mortality by doing prompt diagnosis, triage, and treatment. The treatment of the patients includes aggressive fluid treatment, alkalinization of the urine, hemodialysis, and infection control. Disasters such as earthquakes and other mass accidents, demand preparation of local health-care systems such as ventilators, dialysis machines, and intensive care units.

REFERENCES

Arango-granados, C., Fernando, D., & Mendoza, C. (2020). Amputation in crush syndrome: A case report. *International Journal of Surgery Case Reports*, *72*, 346–350. https://doi.org/10.1016/j.ijscr.2020.05.087

Banerjee, S., Gupta, A., & Jeshwanth, N. (2021). Acute Kidney Injury Secondary to Rhabdomyolysis : A Rare Complication of Low-Energy Trauma. *Journal of Orthopaedic Case Reports*, *11*(1), 16–19. https://doi.org/10.13107/jocr.2021.v11.i01.1946

Belli, T., Buck, J., Davies, T., Doughty, H., Groves, S., Hyatt, L., Jefferson, P., Lee, J., Mahoney, P., Moran, C., Moss, R., Parker, P., Porter, K., Tovey, J., Veen, H., & Wood, P. (2020). Clinical Guidelines for Major Incidents Mass Casualty Events. *NHS Guideline*, *September*, 1–95.

Dimitriou, R., Calori, G. M., & Giannoudis, P. (2011). Polytrauma in the elderly: Specific considerations and current concepts of management. *Eur J Emerg Surg*, *37*, 539–548. https://doi.org/10.1007/s00068-011-0137-y

Esposito, P., Estienne, L., Serpieri, N., Ronchi, D., Comi, G. P., Moggio, M., Peverelli, L.,

Bianzina, S., & Rampino, T. (2018). Rhabdomyolysis-Associated Acute Kidney Injury. *American Journal of Kidney Diseases*, *71*(6), A12–A14. https://doi.org/10.1053/j.ajkd.2018.03.009

Ferla, F., Ciravegna, A., Mariani, A., Buscemi, V., Carlis, R. De, & Aseni, P. (2018). Acute Compartment Syndrome. In *Operative Techniques and Recent Advances in Acute Care and Emergency Surgery, StatPearls Publishing* (pp. 715–725). https://doi.org/10.1007/978-3-319-95114-0

Huq, S. M. R., Anam, A. M., Rabbani, R., Uddin, M. N., Polash, M. M. I., & Nessa, S. S. T. (2017). Update on Management of Rhabdomyolysis–A Review. *Bangladesh Crit Care*, *5*(2), 97–101.

Jagodzinski, N. A., Weerasinghe, C., & Porter, K. (2010). Crush injuries and crush syndrome – a review. Part 1: the systemic injury. *Trauma*, *12*, 69–88. https://doi.org/10.1177/1460408610372440

Jin, H., Lin, X., Liu, Z., Wang, J., Wang, J., Zhang, Y., Cao, C., Chai, Y., & Shou, S. (2022). Remote ischemic postconditioning protects against crush - induced acute kidney injury via down - regulation of apoptosis and senescence. *European Journal of Trauma and Emergency Surgery*, *48*(6), 4585–4593. https://doi.org/10.1007/s00068-022-01910-5

Kandemir, E., & Gul, F. (2023). Management of Crush-related Acute Kidney Injury After Disasters. *Balkan Med J,* *40*(2), 72–73. https://doi.org/10.4274/balkanmedj.galenos.2023.27022023

Kodadek, L., Ii, S. P. C., Seshadri, A., Pathak, A., Hoth, J., Appelbaum, R., Michetti, C. P., & Gonzalez, R. P. (2022). Rhabdomyolysis: an American Association for the Surgery of Trauma Critical Care Committee Clinical Consensus Document. *Trauma Surg Acute Care*, 1–7. https://doi.org/10.1136/tsaco-2021-000836

Li, N., Wang, X., Wang, P., Fan, H., Hou, S., & Gong, Y. (2020). Emerging medical therapies in crush syndrome–progress report from basic sciences and potential future avenues. *Renal Failure*, *42*(1), 656–666. https://doi.org/10.1080/0886022X.2020.1792928

Li, W., Qian, J., Liu, X., Zhang, Q., Wang, L., Chen, D., & Lin, Z. (2009). Management of severe crush injury in a front-line tent ICU after 2008 Wenchuan earthquake in China: an experience with 32 cases. *Critical Care*, *13*(6), 1–8. https://doi.org/10.1186/cc8160

Rajagopalan, C. S. (2010). Crush Injuries and the Crush Syndrome. *MJAFI*, *66*, 317–320. https://doi.org/10.1016/S0377-1237(10)80007-3

Torres, P. A., Helmstetter, J. A., Kaye, A. M., & Kaye, A. D. (2015). Rhabdomyolysis: Pathogenesis, Diagnosis, and Treatment. *The Ochsner Journal*, *504*, 58–69.

Yazıcı, R., İlçin, C., Özsu, T., Demirtakan, T., Kalafat, U. M., & Doğan, S. (2023). A Comprehensive Review for Refreshing the Crush Syndrome Knowledge After the Devastating Earthquake in Türkiye. *Comprehensive Medicine*, *15*(2), 165–170. https://doi.org/10.14744/cm.2023.03511

Yokota, J. (2005). Crush Syndrome in Disaster. *JMAJ*, *48*(7), 341–352.