Veno-Arterial Extracorporeal Membrane Oxygenation for Electrical Injury Induced Cardiogenic Shock Support: A Case Report

CURRENT STATUS: UNDER REVIEW

Tamer Jamal
Baruch Padeh Medical Center Poriya

Amjad Shalabi
Baruch Padeh Medical Center Poriya

Liza Grosman-Rimon
Baruch Padeh Medical Center Poriya
**Corresponding Author**
**ORCiD:** 0000-0003-1456-6083

Diab Ghanim
Baruch Padeh Medical Center Poriya

Offer Amir
Baruch Padeh Medical Center Poriya

Erez Kachel
Sheba Medical Center at Tel Hashomer

DOI:
10.21203/rs.2.24211/v1

**SUBJECT AREAS**
Cardiothoracic Surgery

**KEYWORDS**
Extracorporeal Membrane Oxygenation; Cardiogenic Shock Support; Electrical Injury: Case Report
Abstract

Background

High voltage electrical injury (HVEI) of more than 1,000V is a potentially devastating form of a multisystem injury associated with high morbidity and mortality.

We present the first case of veno-arterial extracorporeal membrane oxygenation (VA-ECMO) as a life saving device for treating a patient with severe cardiogenic shock after a high voltage electrical injury.

Case Presentation

A 26-year-old male sustained HVEI while working with a concrete mixer pump that came in contact with a high voltage cable of 10,000 volts. He was immediately disconnected from the mixer pump, underwent cardiopulmonary resuscitation and transported to the nearest medical centre with severe cardiogenic shock with ejection fraction (EF) < 10%.

Upon arrival he was in critical condition, sedated and mechanically ventilated, haemodynamically unstable and supported by intravenous (IV) inotropes after a few events of ventricular fibrillation, with an electrical entry point on the left hand and an exit point in his right leg. Blood pH was 6.8, PCO$_2$ 53 mmHg, PaO$_2$ of 57 mmHg, lactate 8 mmol/L, and Troponin 38000 ng/dl. EF was 10% with a global severe left ventricular dysfunction. During cardiopulmonary resuscitation (CPR) including cardiac massage and few electrical shocks he was immediately connected to the VA-ECMO via open right femoral approach with distal arterial leg perfusion.

He was treated with IV broad spectrum antibiotics, and high volume fluids to prevent rhabdomyolysis-induced acute kidney injury, total parenteral nutrition, topical silver sulfadiazine cream, and Granuflex for severe electrical burns. He was gradually weaned from inotropes over the next 3 days, during which his clinical condition and bloodwork
improved tremendously. His EF gradually increased to 50% and he was weaned from the VA-ECMO and underwent decannulation 86 hours after initialization. He was discharged on day 27 without any sequelae.

**Conclusion**

VA-ECMO treatment can be a lifesaving device for treating severe cardiogenic shock caused by high voltage electrical injury, and should be considered while treating these “high-mortality risk” patients.

**Introduction**

Electrical injury is an infrequent but potentially devastating form of multisystem injury associated with high morbidity and mortality.\(^1\) Despite significant improvement in injury prevention and implementation of safety protocols at work places, electrical injury accounts for more than 500 deaths per year in the United States with a mortality rate of 10–30%.\(^2\) Electrical injuries are divided into low-voltage electric power injuries (less than 1,000V) and high-voltage (more than 1,000V).\(^2\)

Cardiac injuries induced by electrical shock can be divided into arrhythmias, conduction abnormalities, and myocardial damage – whether direct electricity exposure or secondary myocardial injury after hypotension or coronary arteries spasm.\(^3\)–\(^5\) Early treatment of cardiogenic shock with appropriate circulation’s support may be vital with veno-arterial extracorporeal membrane oxygenation (VA-ECMO) as one of the therapeutic armamentarium in refractory cardiogenic shock.\(^6\)

Although veno-venous- ECMO (VV-ECMO) was used previously to support lung failure after electrical injury \(^7\), the VA-ECMO to support cardiogenic shock secondary to high voltage electrical injury has not yet being described. We present the first case demonstrating the role of VA-ECMO in resuscitating electrically injured patients.
Case Presentation

A 26-year-old man sustained a high voltage electrical injury (> 1000 volts) while he was working with a concrete mixer pump that came in contact with high voltage cable of 10000 volts. The patient was disconnected from the tube immediately due to the jolt, lost consciousness and cardiac massage launched within 3 minutes by witnesses. Then, advanced life support was supplied by paramedics as ventricular fibrillation was detected. He was referred to the nearby emergency room (ER) of a secondary hospital with cardiogenic shock, being chest compressed by a LUCAS machine. In the emergency room (ER), advanced cardiovascular life support continued for more than 30 minutes.

Insert Figure 1 here.

After his resuscitation, he was still supported with IV Noradrenaline. He was then referred to our institute. Physical exam on his admission showed unconscious ventilated patient with reactive dilated pupil, tachycardia and normal bilateral vesicular breathing sound. Electrical entry point was detected on the left hand; exist points were on the feet bilaterally. ECGs showed sinus tachycardia with PVCs. Arterial blood test showed: PH 6.8, PCO$_2$ 53mmHG, PaO$_2$ 57 mmHg and lactate 8 mmol/l, troponin 38000 ng/dl. ECG showed estimated ejection fraction (EF) 10% with global dysfunction and reserved valves’ function. After the Heart team consult, the patient was connected to VA-ECMO within 30 minutes of his admission, via right femoral approach with distal perfusion.

Management

VA-ECMO support was supplied for 86 hours (3.6 days).

Through this period multiple signs and blood tests were flowed up, among them those related to VA-ECMO (Tables 1 and 2).
Table 1
Patient’s Clinical Outcomes

| Clinical Outcomes         |                  |
|---------------------------|------------------|
| Flow                      | 4 L/MIN          |
| Round per minute          | 3360             |
| Pre-membranous pressure   | 200              |
| Post-membranous pressure  | 170              |
| ECMO FIO2                 | 60%              |
| ACT                       | 180–220          |
| BRAIN SAT                 | 70%              |
| PUPIL EXAM                | ROUND, REACTIVE TO LIGHT |
| LOWER LIMB SAT            | RIGHT 90%, LEFT 70% |

Table 2
Patient’s Biomarker Levels Before, During cannulation after ECMO

|                      | day 1 of admission | After 2 days on ECMO | 1 day after ECMO decannulation | ARDS and referral day |
|----------------------|--------------------|----------------------|-------------------------------|-----------------------|
| WBC (uL/1000)        | 36.6               | 18                   | 19                            | 25                    |
| HEMOGLOBIN (g/dl)    | 18                 | 10                   | 9.9                           | 9.6                   |
| PLATELETS (uL/1000)  | 343                | 167                  | 150                           | 950                   |
| CREATININE (mg/dl)   | 1.5                | 1.1                  | 1                             | 2.5                   |
| LDH (U/L)            | 1315               | 1650                 | 950                           | 950                   |
| CPK (U/L)            | 8250               | 18000                | 10000                         | 2800                  |
| AST (U/L)            | 1200               | 450                  | 450                           | 270                   |
| ALT (U/L)            | 425                | 150                  | 150                           | 130                   |
| LACTATE (mmol/l)     | 8                  | 0.6                  | 1.4                           | 1.9                   |
| PH                   | 6.8                | 7.45                 | 7.4                           | 7.32                  |

Other points of care that were served: Suspicion of aspiration on the day of admission; he was treated by antibiotics. Diagnosis of right pleural effusion which was drained by chest tube. Fluid administration to prevent rhabdomyolysis induced acute kidney injury. Total parenteral nutrition for visceral electrical injury resulted in decreased enteral absorption. Burn wounds were treated locally by silver sulfadiazine cream (Silverol) and Granuflex dressing.

Outcomes

Within the first day, the patient had been weaned from noradrenaline. Lactate declined gradually down until 0.6 mmol/L. Follow up echocardiography on the third day showed improvement in cardiac function with EF = 50% and normal right ventricular function. After 86 hours of mechanical support, the patient underwent decannulation from VA-ECMO.
Acute respiratory distress syndrome (ARDS) was diagnosed on the 6th day of hospitalization and was treated accordingly. On the seventh day, the patient was referred to ARDS specialized department in a primary medical centre being anesthetised and ventilated for continuous treatment. There, he was hospitalized for almost a month. During this period he passed tracheostomy and then gradual weaning and respiratory physiotherapy up until discharge. Two months after the accident, he was discharged for a rehabilitation centre.

Discussion

The patient presented with high voltage electrical burn induced cardiogenic shock with multi-organ failure; instant transthoracic ECG indicated EF of 10%. He was immediately supported by VA-ECMO to stabilize his hemodynamic and to initiate other supportive therapies for the target organs.

To our knowledge, veno-venous-ECMO (VV-ECMO) was used to support lung failure after electrical injury. However, this is the first report of cardiogenic shock requiring VA-ECMO support secondary to high voltage electrical injury. For note, VA-ECMO treatments may not be effective in all high voltage electrical injury cases.

Cardiac injury after an electrical jolt may happen due to arrhythmias - ventricular fibrillation can occur with low-voltage alternating current, whereas asystole is more common with direct current or high-voltage alternating current. The mechanism behind electrically induced cardiac arrhythmias is not entirely clear but may involve patchy areas of myocardial necrosis, which serve as arrhythmogenic foci, as well as increased cardiac sodium-potassium pump activity.

Moreover, electrical exposure may cause direct myocardial tissue damage through
transcardiac passage of the electric current or indirect damage through ischemic injury precipitated by arrhythmia-induced hypotension or coronary artery spasm.\(^3\)

Electrical energy is capable of damaging most organs, depending on current intensity and pathway, which could lead to a life-threatening clinical state \(^5\). Organ damage by electrical energy includes superficial and deep burn wounds, rhabdomyolysis/compartment syndrome, acute renal failure due to myoglobinurea or ischemia as well as respiratory arrest as a result of either direct injury to the respiratory control centre, causing cessation of respiration, or to suffocation secondary to tetanic contractions of the respiratory muscles. \(^5\)

The recovery of these organs' functions is challenging in case of a failing heart. We think in such electrically injured moribund patients, VA-ECMO can be an instant salvage for mechanical circulatory support and can help in restoring organs function including the heart. In our case we used VA-ECMO to stabilize the patient instantly and to supply effective support for the organs until the heart regained its own normal function.

Conclusion

VA-ECMO can be a crucial lifesaving device for treating severe cardiogenic shock caused by electrical injury, especially by high voltage electrical injury, and should be considered while treating these high-mortality risk patients.

A List Of Abbreviations

HVEI, high voltage electrical injury

EF, ejection fraction

VA-ECMO, veno-arterial extracorporeal membrane oxygenation

IV, intravenous

CPR, cardiopulmonary resuscitation
ER, emergency room

VV-ECMO, veno-venous-extracorporeal membrane oxygenation

ARDS, acute respiratory distress syndrome

Declarations

**Ethics approval and consent to participate**

This study was approved by the ethics committee of Poriya Medical Center.

**Consent for publication**

A consent was obtained from the patient to publish the case following patients’ recovery.

**Availability of data and materials**

Please contact author for data requests.

**Competing interests**

The authors declare that they have no competing interests.

**Funding**

No funding was received.

**Authors' contributions**

All authors contributed to the manuscript and met the criteria for authorship.

**Acknowledgements**

Not applicable

**References**

1. Shih JG, Shahrokhi S, Jeschke MG. Review of Adult Electrical Burn Injury Outcomes Worldwide: An Analysis of Low-Voltage vs High-Voltage Electrical Injury. *Journal of burn care & research : official publication of the American Burn Association.* 2017;38(1):e293-e298.

2. Daskal Y, Beicker A, Dudkiewicz M, Kessel B. [HIGH VOLTAGE ELECTRIC INJURY:
MECHANISM OF INJURY, CLINICAL FEATURES AND INITIAL EVALUATION]. *Harefuah*. 2019;158(1):65-69.

3. Spies C, Trohman RG. Narrative review: Electrocution and life-threatening electrical injuries. *Ann Intern Med*. 2006;145(7):531-537.

4. Jensen PJ, Thomsen PE, Bagger JP, Norgaard A, Baandrup U. Electrical injury causing ventricular arrhythmias. *British heart journal*. 1987;57(3):279-283.

5. Waldmann V, Narayanan K, Combes N, Jost D, Jouven X, Marijon E. Electrical cardiac injuries: current concepts and management. *Eur Heart J*. 2018;39(16):1459-1465.

6. Vahdatpour C, Collins D, Goldberg S. Cardiogenic Shock. *Journal of the American Heart Association*. 2019;8(8):e011991.

7. Chou NK, Chen YS, Ko WJ, et al. Application of extracorporeal membrane oxygenation in adult burn patients. *Artif Organs*. 2001;25(8):622-626.

Figures
Figure 1

Figure legend not provided with this version.
Supplementary Files

This is a list of supplementary files associated with the primary manuscript. Click to download.

CARE.pdf