

CASE REPORT

Double Sequential Defibrillation for Refractory Ventricular Fibrillation During Resuscitative Thoracotomy: A Case Report

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In-hospital cardiac arrest (IHCA) is associated with improved outcomes compared to out-of-hospital cardiac arrest (OHCA), largely due to immediate access to advanced resuscitative interventions. Double sequential defibrillation (DSD) is an emerging technique that has demonstrated potential benefit in cases of refractory ventricular fibrillation (RVF), though its use has primarily been described in closed-chest resuscitation. We present a case of a male patient of unknown age, estimated to be in his third decade of life, who developed RVF following a penetrating gunshot wound to the abdomen. Despite resuscitative thoracotomy and attempted internal defibrillation, sustained ROSC was not achieved until DSD was performed using external defibrillation pads. DSD was initiated after approximately 11 minutes of unsuccessful standard resuscitative measures, including internal cardiac massage and multiple defibrillation attempts. Although the patient ultimately succumbed to non-survivable aortic injuries discovered intraoperatively, this case demonstrates the feasibility and potential effectiveness of DSD in an open-chest resuscitation setting. To our knowledge, this represents the first reported use of DSD following resuscitative thoracotomy.

Background

Defibrillation, in conjunction with high-quality cardiopulmonary resuscitation (CPR), is the cornerstone of treatment for ventricular fibrillation (VF) cardiac arrest.¹ Standard defibrillation involves placement of external pads in the anterolateral or anterior–posterior configuration, delivering an electrical current that depolarizes myocardial tissue in an effort to terminate malignant arrhythmias and restore organized electrical activity.²

Resuscitative thoracotomy (RT) is a high-risk, time-sensitive intervention reserved for select cases of traumatic cardiac arrest or profound refractory shock. Accepted indications include penetrating thoracic or abdominal trauma with witnessed arrest and a short duration of prehospital CPR (generally <15 minutes for penetrating trauma and <10 minutes for blunt trauma), as well as patients with refractory hypotension due to suspected intrathoracic injury.³ RT allows for direct cardiac massage, relief of pericardial tamponade, control of intrathoracic hemorrhage, aortic cross-clamping, internal cardiac massage, and direct intracardiac defibrillation.

Ventricular fibrillation is associated with improved survival compared with non-shockable rhythms; however, the probability of successful defibrillation decreases with increasing duration of arrest. Refractory ventricular fibrillation (RVF), commonly defined as persistent VF despite three or more defibrillation attempts, is associated with poor outcomes and presents a significant therapeutic challenge.⁴

Double sequential defibrillation (DSD) has emerged as a potential treatment option for RVF. The technique involves the use of two defibrillators and two sets of pads placed in different vectors, commonly anterolateral and anterior-posterior positions. Shocks may be delivered simultaneously or sequentially with a brief delay of one to two seconds.⁴ While the precise mechanism of action remains unclear, proposed theories include higher cumulative energy delivery, altered myocardial vector gradients, and improved defibrillation thresholds. Early reports described DSD primarily as a rescue intervention after prolonged unsuccessful conventional defibrillation attempts.¹ More recently, however, the multicenter DOSE VF randomized trial provided the strongest clinical evidence supporting alternative defibrillation strategies for refractory ventricular fibrillation. Compared with continued standard defibrillation after three failed shocks, double sequential defibrillation significantly improved survival-to-hospital discharge and favorable neurologic outcome, while vector-change defibrillation also improved survival.⁵ Despite these findings, the role of DSD during open-chest resuscitation after failed intracardiac defibrillation has not been described. We report the successful termination of refractory ventricular fibrillation using DSD during open-chest resuscitation after unsuccessful direct intracardiac defibrillation in a patient undergoing resuscitative thoracotomy.

Case Report

An unidentified, male patient of unknown age, estimated to be in his 20s to 30s, presented to the emergency department, with local emergency medical services, after sustaining a gunshot wound to the thoracoabdominal region. The patient lost pulses less than five minutes prior to arrival. Upon arrival, cardiac arrest was confirmed, and resuscitation was initiated in accordance with institutional protocol.

The emergency medicine team secured the airway with a 7.5-mm endotracheal tube while simultaneous bilateral finger thoracostomies were performed, with the right thoracostomy performed by emergency medicine personnel and the left thoracostomy performed by trauma surgery staff. Large-bore vascular access was obtained using a multi-lumen access catheter, and massive transfusion was initiated. Three units of packed red blood cells were administered during the emergency department resuscitation.

Given the patient's pulseless state and penetrating mechanism of injury, the left thoracostomy was converted to a left resuscitative thoracotomy. The pericardium was opened and the myocardium inspected, revealing no evidence of direct cardiac injury or pericardial tamponade. A right thoracotomy was subsequently completed to facilitate bimanual internal cardiac massage.

The presenting rhythm was ventricular fibrillation, and, once direct cardiac access was obtained, internal defibrillation was attempted at 10 joules without successful rhythm conversion. A second attempt at 40 joules was performed; however, only a single low-pitched click was appreciated when the shock button was depressed, without evidence of rhythm change. A subsequent attempt produced similar findings. In the moment, the consensus among the resuscitation team was that effective energy delivery had not occurred because of malfunction of the internal defibrillation equipment.

Recognizing the time-sensitive nature of VF and believing that further delay to troubleshoot the internal paddles would be detrimental, the team elected to proceed with external defibrillation. A standard external shock was delivered without rhythm conversion.

Point-of-care laboratory evaluation demonstrated normal electrolyte values, a pH of 7.35, and a lactate concentration of less than 2 mmol/L, suggesting adequate perfusion during ongoing resuscitation. In conjunction with the patient's apparently young age and brief arrest duration, these findings supported continued aggressive resuscitative efforts.

Persistent ventricular fibrillation despite internal and external defibrillation attempts met criteria for RVF. A second set of external defibrillation pads was applied in a separate vector, and simultaneous shocks were delivered using two defibrillators. Ventricular fibrillation was terminated immediately, resulting in return of spontaneous circulation and restoration of an organized perfusing rhythm approximately eleven minutes after arrest.

Following return of spontaneous circulation, the patient was transferred emergently to the operating room for definitive surgical management. Exploratory laparotomy demonstrated multiple catastrophic injuries to the abdominal aorta that were deemed non-survivable. Despite continued efforts, the patient expired intraoperatively.

Discussion

This case is noteworthy because it describes the successful use of double sequential defibrillation in a patient undergoing open-chest resuscitation following penetrating trauma. To the best of our knowledge, no previously published reports describing the use of DSD following attempted direct intracardiac defibrillation during resuscitative thoracotomy have been identified.

A literature search was performed through June 2026 using PubMed and Google Scholar. Search terms included “double sequential defibrillation,” “dual sequential defibrillation,” “refractory ventricular fibrillation,” “resuscitative thoracotomy,” “open-chest cardiac arrest,” “internal defibrillation,” and “intracardiac defibrillation.” Although multiple reports describing DSD in closed-chest cardiac arrest were identified, no publications describing DSD after attempted internal defibrillation during resuscitative thoracotomy were found.

Ventricular fibrillation is initially highly responsive to electrical defibrillation; however, the probability of successful rhythm conversion decreases with increasing duration of arrest. Progressive myocardial ischemia, depletion of high-energy phosphate stores, acidosis, and rising defibrillation thresholds contribute to the development of refractory ventricular fibrillation. As these physiologic changes occur, conventional defibrillation becomes progressively less effective, necessitating consideration of alternative strategies such as vector change and double sequential defibrillation.² Since completion of the DOSE VF trial, the evidence supporting DSD has continued to evolve. In this randomized cluster-crossover trial, DSD resulted in significantly higher survival-to-hospital discharge and improved neurologic outcomes compared with continued standard defibrillation. Vector-change defibrillation also improved survival, suggesting that alteration of shock vector contributes substantially to successful rhythm conversion. Although DOSE VF evaluated out-of-hospital closed-chest cardiac arrest, our case extends these findings to an entirely different clinical setting. Our patient underwent bilateral thoracotomy with attempted intracardiac defibrillation before successful DSD. To our knowledge, no published reports have described successful DSD following failed intracardiac defibrillation during resuscitative thoracotomy, thereby expanding the potential clinical application of this technique.⁵

Most additional existing literature on DSD describes its use as a late-rescue therapy in cases of prolonged refractory VF during closed-chest resuscitation. Bero et al.¹ reviewed 12 case reports and found that DSD terminated RVF in 76.9% of cases and achieved ROSC in 53.9%. In these cases, patients received an average of six standard defibrillation attempts and experienced a mean arrest duration of 31.4 minutes before DSD was initiated. These observations have prompted interest in whether earlier application of alternative defibrillation strategies may improve rhythm conversion.

Park et al.⁴ reported successful ROSC after DSD was administered following 10 unsuccessful standard defibrillation attempts over a 20-minute arrest period. That patient survived to hospital discharge with favorable neurologic outcome (Cerebral Performance Category 1). However, it is well established that the probability of successful defibrillation decreases as the duration of cardiac arrest increases,¹ raising the question of whether earlier use of DSD could improve survival and neurologic outcomes.

Several mechanisms have been proposed to explain the effectiveness of DSD. One theory suggests that delivery of higher cumulative energy increases the probability of depolarizing a critical mass of myocardium. Another proposes that two shock vectors create altered electrical gradients, allowing previously unengaged myocardial tissue to be recruited and reducing defibrillation thresholds. A third theory suggests that sequential shocks may transiently lower myocardial impedance, thereby enhancing the effectiveness of the second shock.^{1,2}

A unique feature of the present case is the relatively early use of DSD, approximately eleven minutes after arrest. Most published reports describe DSD as a late-rescue therapy after prolonged arrest durations and numerous unsuccessful shocks. Furthermore, internal defibrillation, which theoretically provides more direct myocardial energy delivery than external defibrillation, failed to restore an organized rhythm. Although malfunction of the internal paddles was suspected, the subsequent failure of conventional external defibrillation suggests that the patient had truly developed refractory ventricular fibrillation. The subsequent success of DSD raises the possibility that altered current vectors or increased delivered energy may provide benefits even in the setting of open-chest resuscitation.

Point-of-care laboratory studies demonstrated normal electrolyte values, physiologic acid-base status, and a lactate concentration below 2 mmol/L. These findings suggested preserved tissue perfusion during resuscitation and a potentially salvageable myocardium. Combined with the patient's young age and short arrest duration, these factors influenced the decision to pursue continued aggressive resuscitation and early escalation to DSD.

Although this single case cannot establish causality or define the role of DSD in traumatic cardiac arrest, it demonstrates that DSD can successfully terminate refractory ventricular fibrillation even during open-chest resuscitation after attempted direct intracardiac defibrillation. Additional investigation is needed to better define the optimal timing, energy settings, and patient selection for DSD in both traumatic and non-traumatic cardiac arrest. It complements the growing body of evidence supporting earlier consideration of alternative defibrillation strategies in refractory ventricular fibrillation. Our experience suggests that DSD may remain effective even after unsuccessful internal defibrillation during resuscitative thoracotomy, a setting not represented in existing randomized trials.

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