CASE REPORT

Successful Defibrillation at a Core Temperature of 18.2 Degrees Celsius

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Both the temperature at which defibrillation can be effectively used and how often it should be repeated in severe accidental hypothermia have not been definitely established. Current recommendations are based mainly on expert opinion and suggest withholding defibrillation after 3 shocks when the core temperature is below 30°C (86°F). However, growing evidence supports the effectiveness of defibrillation in patients with a core temperature below 30°C (86°F). We present a case of successful defibrillation of a 54-y-old, severely hypothermic patient with a core temperature of 18.2°C (64.8°F). The shock was delivered automatically by an implanted cardioverter-defibrillator shortly after the implementation of extracorporeal rewarming. The patient survived and was discharged from the hospital neurologically intact. It might be reasonable to consider defibrillation attempts in severely hypothermic patients despite current guidelines to the contrary. Increasing coronary perfusion using extracorporeal circulation may result in a better response to defibrillation.

Keywords: hypothermia, cardiopulmonary resuscitation, implantable cardioverter-defibrillator, extracorporeal life support

Introduction

Both the temperature at which defibrillation can be effectively used and how often it should be repeated in a severely hypothermic patient have not been definitely established. If ventricular fibrillation (VF) persists after 3 shocks, it is recommended to delay further attempts until the core temperature (T_c) rises to or above 30°C (86°F).¹ Although the value of deferring subsequent defibrillations until a target temperature is achieved is uncertain, it may be reasonable to perform further defibrillation attempts according to the standard basic life support algorithm concurrent with rewarming strategies.² According to the Wilderness Medical Society clinical practice guidelines, if a single shock at

a temperature below 30°C (86°F) is unsuccessful, further shocks after rewarming at least 1 to 2°C may be justified.³ Surprisingly, all of these recommendations are based on animal studies and several human case reports, with no supporting high-quality study.

We present a case of successful defibrillation of a patient with a T_c of 18.2°C (64.8°F). The shock was delivered automatically by an implanted cardioverter-defibrillator (ICD).

Case Presentation

A 54-y-old man was found apparently lifeless in the forest on a winter morning. The average outside temperature that day was −7°C (19°F). His exposure time and the reason he was alone in the woods were not known. An ambulance was called to the scene. At 0915, paramedics found the patient unresponsive with no signs of life. Measurement of T_c was unavailable. Hypothermia was diagnosed based on a history of exposure to cold and clinical examination

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Figure 1. Appropriate implanted cardioverter-defibrillator shock therapy at 15 J followed by a temporarily nonsinus rhythm and then effective VVI pacing at 50 beats $\cdot$ min $^{-1}$ (1207).

in which the trunk felt very cold. Cardiac arrest was diagnosed based on clinical examination and cardiac monitoring, which showed a nonshockable rhythm. End-tidal CO₂ monitoring was unavailable.

At 0918, cardiopulmonary resuscitation (CPR) was started. The patient was intubated and ventilated with 100% F_IO₂. At 0949 and 1006, 2 manual monophasic external defibrillations of 200 J and 360 J were delivered, respectively. The patient was insulated in a rescue bag. Medical personnel were unaware that 5 mo earlier, the patient had had an ICD implanted (St Jude's Ellipse VR, Mode VVI 50 beats $\cdot$ min $^{-1}$, VT zone: 184 beats $\cdot$ min $^{-1}$, VF zone: 230 beats $\cdot$ min $^{-1}$) to prevent sudden cardiac death.

A helicopter was called. Once on scene, the helicopter emergency medical services team decided to transport the patient with ongoing mechanical chest compressions to the nearest center capable of extracorporeal rewarming. On arrival at the John Paul II hospital in Krakow (1134), the patient was asystolic and the T_c was 17.8°C (64°F) by esophageal probe. At 1157, extracorporeal membrane oxygenation rewarming was instituted. Arterial blood gas

measurements less than 5 min after starting extracorporeal membrane oxygenation were pH of 7.14, arterial partial pressure of oxygen of 304 mm Hg, arterial partial pressure of carbon dioxide of 42 mm Hg, and base excess of -14.5 mm Hg. Serum potassium was 3.5 mmol $\cdot$ L $^{-1}$. At 1207, at a T_c of 18.2°C (64.8°F), a 15 J shock delivered by an ICD restored sinus rhythm with subsequent effective VVI stimulation at 50 beats $\cdot$ min $^{-1}$ (Figure 1). The patient survived and was discharged from the hospital neurologically intact. Appropriate battery voltage and normal circuitry function were found in the ICD in the postevent evaluation.

Analysis of the ICD recordings revealed 18 tachyarrhythmic events on the day the patient was found. We present detailed information including the shock delivered and the duration and outcome of the event in Table 1.

Discussion

The patient gave written informed consent to publication of this case. The most important message is that successful defibrillation in severe hypothermia is possible at a T_c as low as 18.2°C (64.8°F). This case indicates the potential

Table 1. Compiled report of intracardiac electrogram and surface electrocardiograms and core temperature

Time	
0918	IEGM record (11/28); Episode: nonsustained (243 min ⁻¹ /246 ms) zone nearest detection VF, duration 12 s; record description: patient's heart rhythm 60–75 beats·min ⁻¹ , artifacts related to external chest compressions, therapy not delivered
0920	ECG: asystole—VVI pacing 50 beats·min ⁻¹ , failure to capture
0949	ECG: VF—external defibrillation 200 J followed by VVI stimulation 50 beats·min ⁻¹ and short-lived ROSC (NIBP 50/20 mm Hg), refrillation
0954	ECG—asystole—VVI pacing 50 beats·min ⁻¹ , failure to capture
0959	ECG: VF seen on the external monitor
1004	IEGM record (12/28); Episode: nonsustained (240 min ⁻¹ /250 ms) zone nearest detection VF, ^a duration 10 s. Record description: artifacts related to external chest compressions, therapy not delivered
1005	IEGM record (13/28); Episode: nonsustained (237 min ⁻¹ /253 ms) zone nearest detection VF, ^a duration 18 s, record description: artifacts related to external chest compressions, therapy not delivered
1005	IEGM record (14/28); Episode: nonsustained (229 min ⁻¹ /261 ms) zone nearest detection VF, ^a duration 4 s. Record description: artifacts related to external chest compressions, therapy not delivered
1006	IEGM record (15/28); Episode: nonsustained (229 min ⁻¹ /261 ms) zone nearest detection VF, ^a duration 20 s. Record description: artifacts related to external chest compressions, therapy not delivered
1006	ECG: VF—external defibrillation 360 J followed by VVI stimulation 50 beats·min ⁻¹ and short-lived ROSC, refrillation
1049	ECG: VF seen on the external monitor
1128	ECG: Asystole seen on the external monitor, VVI ineffective
1134	T_c 17.8°C
1135	ECG: VF seen on the external monitor
1157	ECMO rewarming instituted
1202	IEGM record (16/28); Episode: VF (255 min ⁻¹ /235 ms), duration 18 s, detection criteria 230 min ⁻¹ – 15 J, record description: VF – appropriate ICD shock therapy 15 J, patient's heart rhythm 11 QRSs, refrillation
1203	IEGM record (17/28); Episode: VF (230 min ⁻¹ /260 ms), duration 22 s, detection criteria 230 min ⁻¹ , 1xATP during charging “on,” defibrillation 15 J. Record description: VF—appropriate ICD shock therapy 15 J, ATP 1x during charging “on” patient's heart rhythm 8 QRSs, refrillation
1203	IEGM record (18/28); Episode: VF (240 min ⁻¹ /250 ms), duration 34 s, detection criteria 230 min ⁻¹ , 1x ATP during charging “on,” defibrillation 15 J, aborted defibrillation 30 J. Record description: VF—appropriate ICD shock therapy 15 J, ATP 1x during charging “on” patient's heart rhythm 7 QRSs, VF/artifacts redetected—30 J aborted
1204	IEGM record (19/28); Episode: VF (255 min ⁻¹ /235 ms), duration 16 s, detection criteria 230 min ⁻¹ , defibrillation 15 J. Record description: VF—appropriate ICD shock therapy 15 J, patient's heart rhythm 7 QRSs, next VF/artifacts probably related to external chest compressions
1204	IEGM record (20/28); Episode: VF (230 min ⁻¹ /260 ms), duration 36 s, detection criteria 230 min ⁻¹ , 1xATP during charging “on,” defibrillation 15 J. Record description: VF—appropriate ICD shock therapy 15 J, ATP 1x during charging “on” patient's heart rhythm 2 QRSs, artifacts probably related to external chest compressions
1205	IEGM record (21/28); Episode: nonsustained (256 min ⁻¹ /234 ms) zone nearest detection VF, duration 8 s. Record description: shock 15J, artefacts
1205	IEGM unavailable (22/28)—nonsustained (270 min ⁻¹ /222 ms) zone nearest detection VF, duration 4 s, no therapy delivered
1205	IEGM record (23/28); Episode: VF (230 min ⁻¹ /260 ms), duration 18 s, detection criteria 230 min ⁻¹ , 1x ATP during charging “on,” aborted defibrillation 15 J. Record description: VF ATP 1x during charging, artifacts redetected, probably related to external chest compressions
1205	IEGM record (24/28); Episode: nonsustained (229 min ⁻¹ /261 ms) zone nearest detection VF, duration 14 s, no therapy delivered. Record description, shock 15 J, artifacts probably related to external chest compressions
1206	IEGM unavailable (25/28)—nonsustained (265 min ⁻¹ /226 ms) zone nearest detection VF, duration 18 s, no therapy delivered
1206	IEGM unavailable (26/28)—nonsustained (256 min ⁻¹ /234 ms) zone nearest detection VF, duration 8 s, no therapy delivered
1206	IEGM record (27/28); Episode: nonsustained (229 min ⁻¹ /261 ms) zone nearest detection VF, duration 24 s, no therapy delivered. Record description: artifacts probably related to external chest compressions
1207	T_c 18.2°C
1207	IEGM record (28/28); Episode: VF (260 min ⁻¹ /230 ms), duration 28 s, detection criteria 230 min ⁻¹ , defibrillation 15 J. Record description: VF—appropriate ICD shock therapy 15 J followed by effective VVI pacing 50 beats·min ⁻¹ , Figure 1

ATP, antitachycardia pacing; ECMO, extracorporeal membrane oxygenation; ICD, implantable cardioverter defibrillator; IEGM, intracardiac electrogram; T_c, core temperature; VF, ventricular fibrillation.

^a The arrhythmia would be classified as VF if it continued rather than reverting to a sinus rhythm/nonsinus rhythm.

value of administering shocks during rewarming, even if the T_c is lower than 30°C (86°F).

There is a lack of experimental and clinical data on the effects of hypothermia on resuscitation and, in particular, on defibrillation. The extent to which hypothermia contributes to arrhythmogenesis and the mechanisms involved are not well defined. VF should be treated immediately with defibrillation. In hypothermia, if initial attempts at defibrillation are unsuccessful, further attempts and antiarrhythmic medications should be withheld until the patient is warmed to above 30°C (86°F).^{1,2} However, the value of deferring subsequent defibrillations until a target temperature is achieved is uncertain.²

There are several case reports supporting the effectiveness of defibrillation in patients with a T_c below 30°C (86°F).^{4–10} The success rate of defibrillation attempts may be higher than widely assumed. A T_c above 24°C (75.2°F) may be associated with successful defibrillation.⁵

Current evidence suggests that an increase in T_c during active rewarming may improve defibrillation success.^{4–10} At least one-third of successful defibrillations at a T_c lower than 30°C (86°F) were in patients who underwent rewarming before shocks restored spontaneous circulation.^{4–10} Active rewarming should be started as early as possible when transfer to extracorporeal circulation is not an option.^{3,5} It is unclear whether the likelihood of successful defibrillation is increased by the increase in T_c , by the increase in myocardial perfusion, or by the direct rewarming of the myocardium with warmer blood in the coronary arteries.

Successful defibrillation at a T_c below 28°C (82.4°F) has been reported in patients with extracorporeal circulatory support and optimized myocardial perfusion.^{5,9,10} In a study of 23 severely hypothermic patients, none of the patients with witnessed VF arrest were defibrillated before extracorporeal rewarming was started.¹¹

In the present case, the T_c increased only minimally, but perfusion increased significantly before the successful shock was delivered. This suggests that the key to successful defibrillation in severely hypothermic patients is the optimization of myocardial perfusion. We believe that the current case is the first reported occurrence of successful ICD defibrillation in hypothermic cardiac arrest. The device can store information about events, including electrograms. Electrograms are electrocardiographic records obtained from inside the heart. The capability to store electrograms offers the possibility to characterize arrhythmias associated with hypothermic cardiac arrest and the effectiveness of defibrillation attempts by the ICD. The first electrogram recorded during the event was at a heart rate of 60 to 75 beats·min⁻¹ and contained artifacts related to external chest compressions (Table 1). The ICD recognized a potentially perfusing rhythm and

did not deliver a shock. There is a risk of misdiagnosis of a perfusing rhythm as a nonperfusing one. If a cardiac monitor shows an organized rhythm without detectable pulses, it may be pulseless electrical activity or a perfusing rhythm with very weak pulses.³

Severe hypothermia is associated with marked depression of critical body functions, which may make the victim appear clinically dead during the initial assessment. The traditional method of checking for a faint pulse with fingers placed over an artery is limited by cold, tissue stiffness, and impaired sensitivity of rescuer's fingers.³ Adhesive pads for monitor leads do not stick well to cold skin, and conduction of electrical signals across cold skin may be impaired.¹² Starting CPR in a hypothermic patient with an organized cardiac rhythm carries a risk of causing VF that would convert a perfusing rhythm into a nonperfusing one.^{1,3} Rescuers should look for signs of life for at least 1 min and should use a cardiac monitor to detect any electrical activity.¹ If ETCO₂ monitoring is available, it should be used not only as an indicator of correct positioning of the endotracheal tube but also as a sign of effective circulation.^{3,13} If ultrasound is available, echocardiography can be used to verify cardiac activity.³

Conclusions

Successful defibrillation in severe hypothermia is possible at a T_c as low as 18.2°C (64.8°F) in patients with optimized perfusion. All available measures should be taken to confirm cardiac arrest before initiation of CPR in hypothermic patients.

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