Emergency Care and Resuscitation

SMART Biphasic

SMART Biphasic therapy from Philips

How defibrillators work

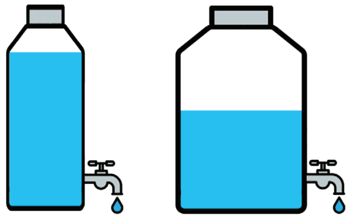
- **Energy:** The ability to do work measured in Joules.
- **Voltage:** Electric potential.
- **Capacitor:** Stores energy in electrical form. In this case, high electric potential.
- **Capacitance:** How much charge/electric potential a capacitor can hold, measured in microfarads (µF).
- **Current:** The amount of electrical charge moved around a circuit measured in Amps.
- **Impedance:** Resistance to the flow of electricity measured in Ohms (Ω).

Think of a defibrillator as a battery and a capacitor connected to the heart that uses various electrical components such as resistors, switches, and transformers to control how and when the electricity flows from the battery to the capacitor and to the heart.

When a defibrillator charges, electricity moves from the battery into the capacitor where it quickly accumulates and is released when you push the shock button. This is similar to how the flash on a camera draws energy from the batteries into a capacitor and releases the energy as a burst of light when the shutter button is pressed. The difference is a defibrillator releases the energy as electrical current.

The size of the capacitor determines how many joules are required to fill the capacitor. A smaller capacitor will require fewer joules to deliver the same voltage and current as a larger capacitor. Philips defibrillators use a 100 microfarad capacitor, while some of our competitors use a 200 microfarad capacitor.

Another way to look at this is to think of the capacitor as a water tank. The water represents the joules needed to fill the capacitor, and the pressure of the water flowing through the hose represents voltage and current. If the tank is full, you are going to have more pressure when you turn on the water than if the tank is half full.

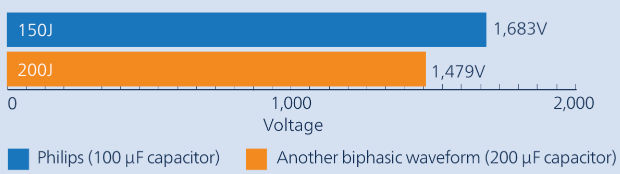


Not all biphasic waveforms are the same

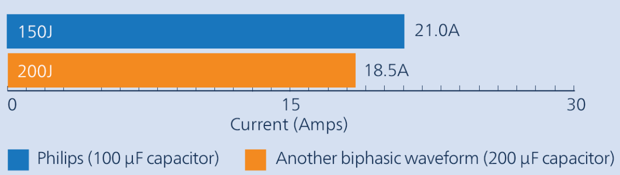
When comparing waveforms from different defibrillator manufacturers, it is important to remember a waveform designed for high energy may not perform effectively at lower energies. This means other defibrillators require more joules to reach the same shock strength as Philips defibrillators.

A defibrillator with a 200 microfarad capacitor needs to deliver close to double the number of joules to match the same current and voltage as a Philips defibrillator set to 200 joules.

Voltage levels by recommended first shock energy setting

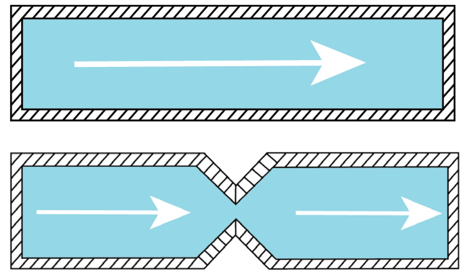


Delivered current by recommended first shock energy setting



Impedance compensation

If you think of voltage as water pressure and current as the flow of water out of a hose, then impedance is determined by the size of the hose. If you have a small garden hose, the impedance would be relatively large and would not allow much water to flow through the hose. Alternatively, if you have a fire hose, the impedance would be lower, and much more water could flow through the hose given the same pressure. The volume of water that comes out of the hose depends on the pressure, the size of the hose, and the amount of time the water flows. A garden hose at a certain pressure for a short period of time works well for watering your garden, but if you used a fire hose with the same pressure and time, you could easily wash your garden away.



Electrical energy is similar. The amount of energy delivered depends on the voltage, the current and the duration of its application. The amount of current that will flow through the patient's chest is determined by the impedance of the body tissue.

Philips defibrillators automatically measure patient impedance and in real-time and dynamically varies the amount of current and the length of time over which the current is delivered. Personalized therapy is delivered to each patient, including the difficult-to-treat ones, starting with the first shock for the best chance of success.

WHY IS CURRENT IMPORTANT?

The term energy does not effectively describe the physiological effects of defibrillation.[1] When a shock is delivered to a patient only about 5% of the electrical current crosses the heart the rest is shunted through the skin, muscle, or bone.[2] Therefore, the higher the initial peak current the more current that passes through the heart.[3]

Cardiac dysfunction from high energy

Animal studies suggest that electric shocks can have a negative inotropic influence on cardiac function depending on the clinical circumstances, the energy dosage, the number of shocks delivered and the underlying cardiac function.[4,5,6] Too many shocks can cause transient cardiac injury, such as decreased contractility and reduced cardiac output during the critical period immediately after severe cardiac compromise. While this type of injury is not permanent, clinical data suggest that during a code this stunning may be significant, complicating subsequent interventions in the emergency department or intensive care unit and potentially impacting patient outcomes.[4,5,7]

Higher-energy defibrillation waveforms, whether monophasic or biphasic, are associated with increased post-shock cardiac dysfunction. Experimental and clinical studies suggest that in typical out-of-hospital multi-shock resuscitations, total energy delivered is a negative predictor of myocardial function.[4,7,8] An animal study noted a correlation between post-resuscitation myocardial dysfunction and early death after initial successful resuscitation.[5]

Tang, et al. compared the impact of various defibrillation waveforms delivered at different energy settings on post-resuscitation myocardial function using an animal model, which effectively isolated the impact of just the defibrillation shocks.[5] The study showed that for swine in long-duration VF, higher current/lower energy and a higher current/higher energy waveform were equally effective at defibrillating. However, the higher energy

Capacitance	100 µF	100 µF	200 µF	200 µF
Energy, J	150	200	200	360
Peak current, amperes	34	40	23.6	37.3
72-h survival	100%	100%	**40%**	100%
Shocks to resuscitate	1	3	**5**	**4**
Duration of CPR, s	106	83	**909**	218
Total delivered energy J	155	563	**994**	**1440**
Ejection fraction	95%	75%	62%	**53%**

waveform was associated with significantly higher levels of harmful cardiac dysfunction.
The table demonstrates that the high energy waveform (200 µF capacitor at 360J) required up to nine times the total energy delivered as the low energy waveform (100 µF capacitor at 150J) to achieve equivalent results.

The table also shows the negative impact of the total delivered energy on ejection fraction, considered a representative measure of dysfunction. Conversely, high peak current was the only positive predictor of increased survival, which reinforces the importance of current in the defibrillation equation.

Tang, et al. concluded that maximizing survival while minimizing myocardial dysfunction may be achieved with a waveform formulation that delivers higher peak current while minimizing total energy delivered.[5] Philips distinct biphasic waveform formulation is able to deliver high peak current at low energy levels. This type of lower energy shock has been shown to have fewer negative inotropic consequences than higher energy shocks. This clinical difference could be particularly meaningful for the long downtime SCA patients, both in and out-of-hospital, who typically require multiple shocks and could help make post-resuscitation interventions in the ED or ICU more successful.

Commitment to SMART Biphasic

All HeartStart AED products use the 150J SMART Biphasic waveform. The Efficia DFM100 defibrillator/monitor and HeartStart Intrepid monitor/defibrillator provide a manual mode of operation for defibrillation and cardioversion as well as an AED mode. These products provide selectable energy settings from 1J to 200J in the manual mode of operation and a constant 150J in the AED mode.

Some waveforms may need more than 200J for defibrillation, but the patented SMART Biphasic waveform does not. Published clinical evidence indicates the SMART Biphasic waveform does not require more than 150J to effectively defibrillate, even if the patient has experienced a heart attack or has a higher-than-normal impedance, or if there have been delays before the first shock is delivered.[5] Published clinical evidence also indicates there is increased dysfunction associated with high-energy shocks.[4,5,7,8,9] The SMART Biphasic waveform has the evidence necessary for conformance with the AHA Class IIa recommendation for low-energy biphasic defibrillation.[10] With this in mind, why would you want to deliver more energy if you didn't have to?

To learn more about Philips defibrillators or purchase an AED, visit www.philips.com/heartstart today.

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00000741-00-00 * FEB 2025
LC2272-007-085