0-48-0295 version B

DEFIBRILLATION
concept & explanations

SCHILLER
The Art of Diagnostics

THE HEART

OPERATION

The heart is composed of 2 independant parts (left and right heart). Each side is is divided in one atrium and one ventricle.

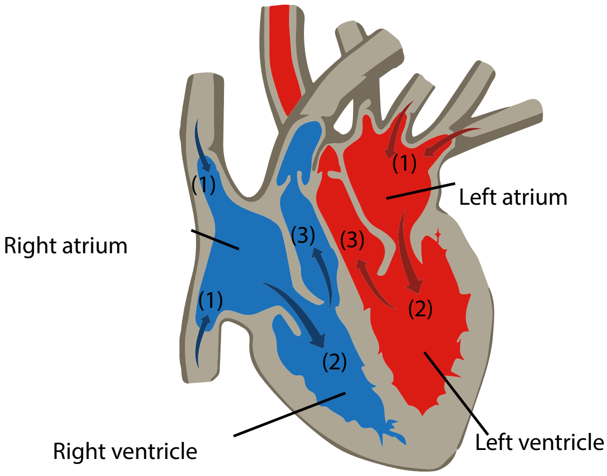


Figure 1: *The cardiac blood cycle*

The blood arrives through the veins (1) in the atria, and is expelled by their contraction to the ventricles (2). The ventricles then contract themselves to expell the blood to the organs through the arteries (3).

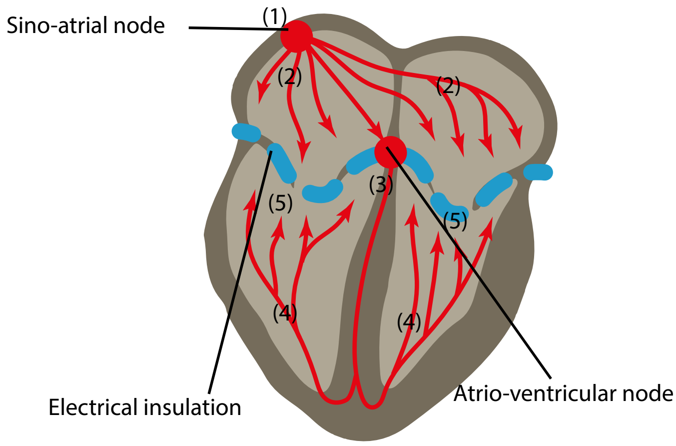


Figure 2: *The cardiac electrical cycle*

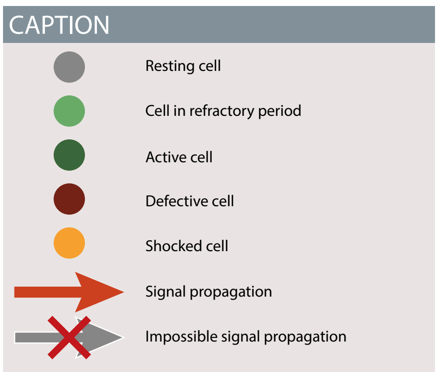
The electrical signal is generated by the sino-atrial node (1). It runs through the atria (2) (contraction of the atria), then reaches the tip of the heart via the atrio-ventricular node (3). The signal propagates through the ventricles (4) (contraction of the ventricles) and stops at the electrical insulation (5) separating the atria and the ventricles.

PROPAGATION OF THE ELECTRICAL SIGNALS

At the cell level, the electrical signal spreads from cell to cell[1].

After being activated, cells are submitted to an inexcitability period of approximativelly 300ms: this is the refractory period (figure 3). The propagation is only possible toward a resting cell.

This causes displacements of fronts of electrical signals (figure 4).



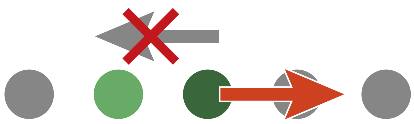


Figure 3: *Refractory period that forces the direction of propagation.*

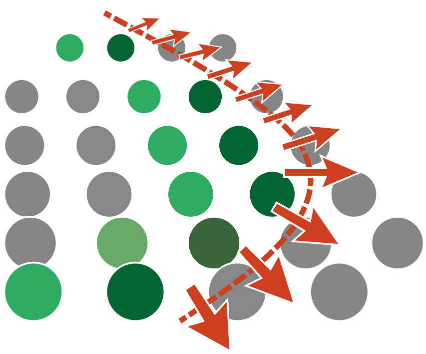


Figure 4: *Propagation of a front of electrical signals.*

VENTRICULAR OR ATRIAL FIBRILLATION (VF/AF)

Obstacles influence the propagation of the electrical signal through the heart. These obstacles can be defective cardiac cells (figure 5).

They could lead to a re-entry phenomenon (figure 6) where electrical signals will circumvent obstacles and go in another direction.

The re-entry phenomenon[2] pushed to the extreme (multiple re-entries), causes the fibrillation (figure 7).

As atria and ventricles are electrically isolated, fibrillation cannot propagate from one to the other. This is thus called either atrial fribrillation or ventricular fibrillation.

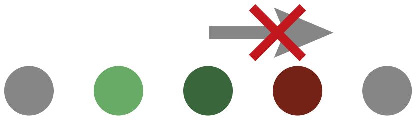


Figure 5: *Stop of the propagation*

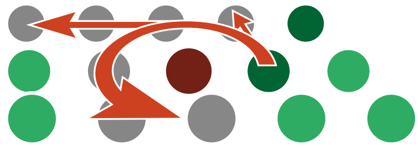


Figure 6: *Re-entry phenomenon*

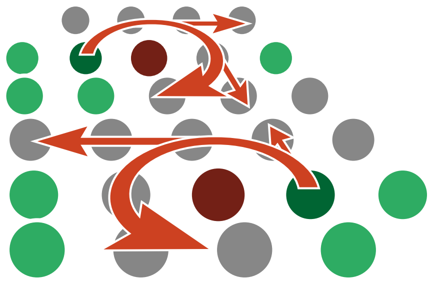


Figure 7: *Fibrillation , multiple sustained re-entries.*

When the heart is in ventricular fibrillation, without any efficient cardio-pulmonary resuscitation (CPR), the blood stops flowing. Each minute, the survival chances decrease by 10% because organs (brain, liver, ...) are no longer irrigated.

THE DEFIBRILLATION

PRINCIPLE

As shown on figures 8 and 9, the electrical signal can only be propagated through an excited cell.
Defibrillation consists in exciting the largest possible number of cardiac cells in order to stop the propagation of electrical signal fronts[3] (figures 10 and 11).

International recommandations from both ERC and AHA* do not advise the use of monophasic defibrillation waveform because it leads to a long period of post-shock sideration (electrical silence of the heart). This is due to the lack of a forced rebalancing of charges on the boundaries of the cellular membranes.
The second phase of the biphasic waveform allows this rebalancing, avoiding the post-shock sideration

Figure 8: *Propagation just before the shock.*

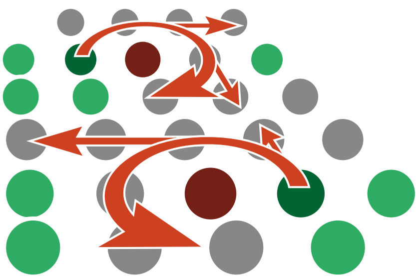


Figure 9: *Propagation of fronts of electrical signals just before the shock.*

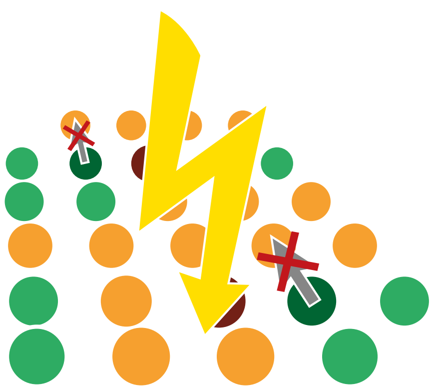


Figure 10: *Fibrillation stopped by the shock.*

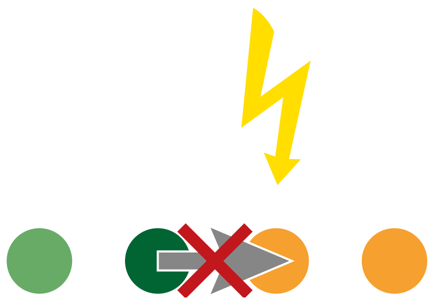


Figure 11 : *Propagation stopped by the shock*

**European Research Council (ERC), American Heart Association (AHA) : Scientific commitees*

EXTERNAL DEFIBRILLATION AT LOWER RISKS

THE CHRONAXIE TIME [4]

A strong electrical current is necessary to put all cells in their excited state. However, this energy must be delivered in a very short period of time, as close as possible to the chronaxie time (figure 12), in order to avoid harming the patient's body.

*The **chronaxie time** is the duration that allows an efficient excitement of a set of cells, using the least possible energy. On human beings, its value ranges from 2 to 6 ms.[5]*

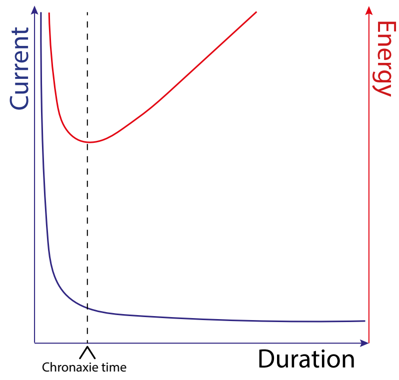


Figure 12: *Minimal current and energy necessary to excite a set of cells for a given application duration.*

CONSTANT ENERGY

During defibrillation, according to the physical law U = R x I and considering that the voltage is constant, the higher the impedance of the patient is, the lower the current passing through the patient will be (figure 13). In order to provide a constant energy to the patient, an impedance compensation is necessary.

The transthoracic impedance varies with multiples parameters:

- The size of the electrodes
- The skin-electrode interface
- The rib cage volume
- The skin texture
- The patient's corpulence

*The **transthoracic impedance** (or impedance of the patient), is the ability of the thorax to resist against the electrical current flow.*

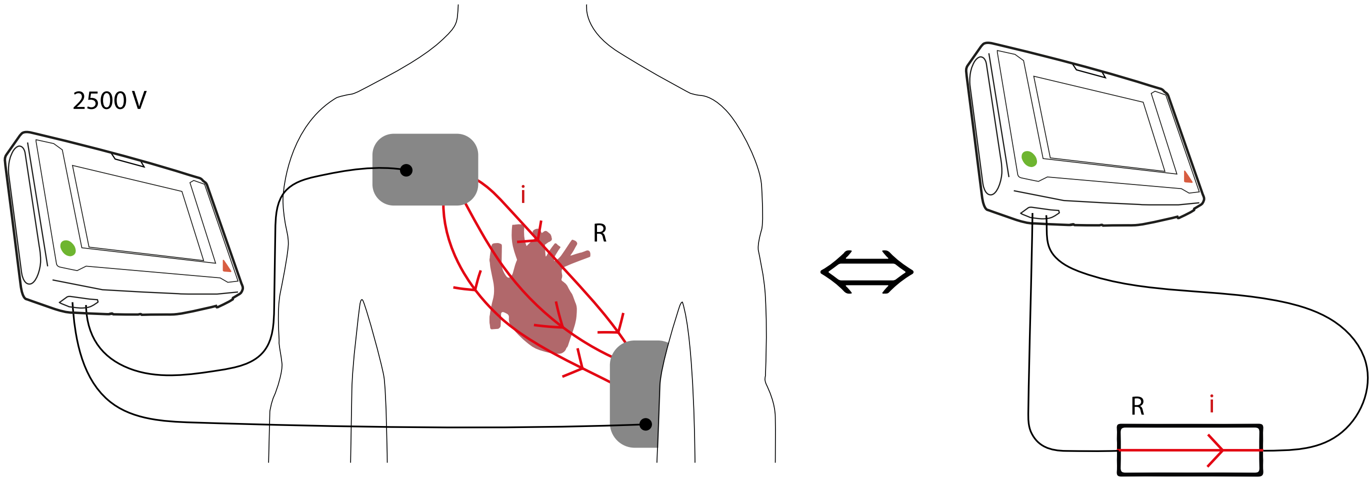


Figure 13: *Equivalence between the thorax impedance of a patient and a standard resistor.*

ELECTROPORATION [6]

When a cell is submitted to a voltage gradient above 25 to 30V/cm, pores form at the surface to let the current cross through. This is called electroporation.

This phenomenon is reversible and even necessary during an external defibrillation shock (figure 14). If the voltage gradient is too high or applied during an excessive period, pores may never close themselves. The phenomenon is then irreversible, causing the cell death (figure 15).

*The **voltage gradient** is a tension expressed per length unit. For instance, 100V applied on 1cm (100V/cm)*

The irreversible electroporation risk is nonexistent when applying a voltage gradient lower than 100V/cm for less than 20ms.

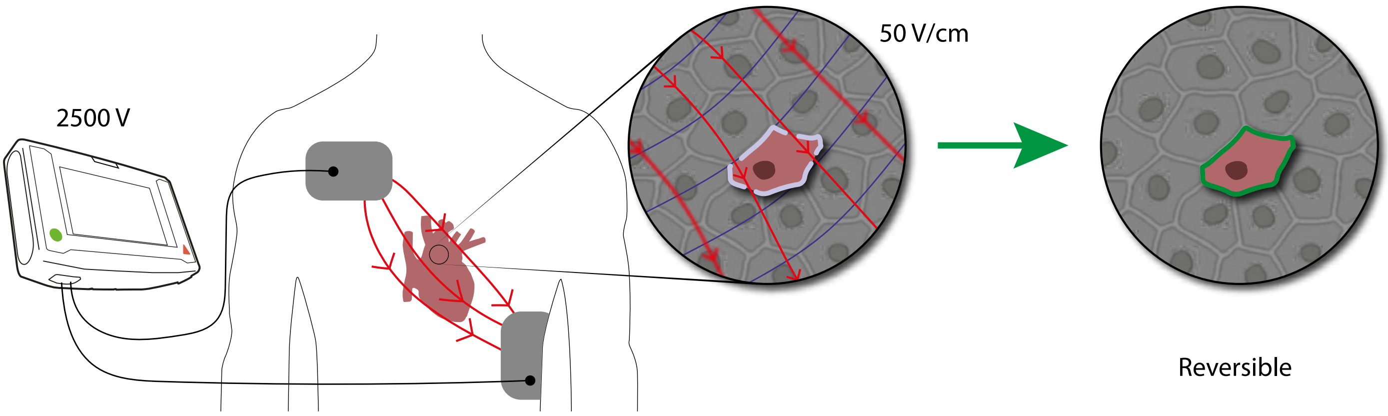


Figure 14: *Reversible electroporation with a tension of 2500 V.*

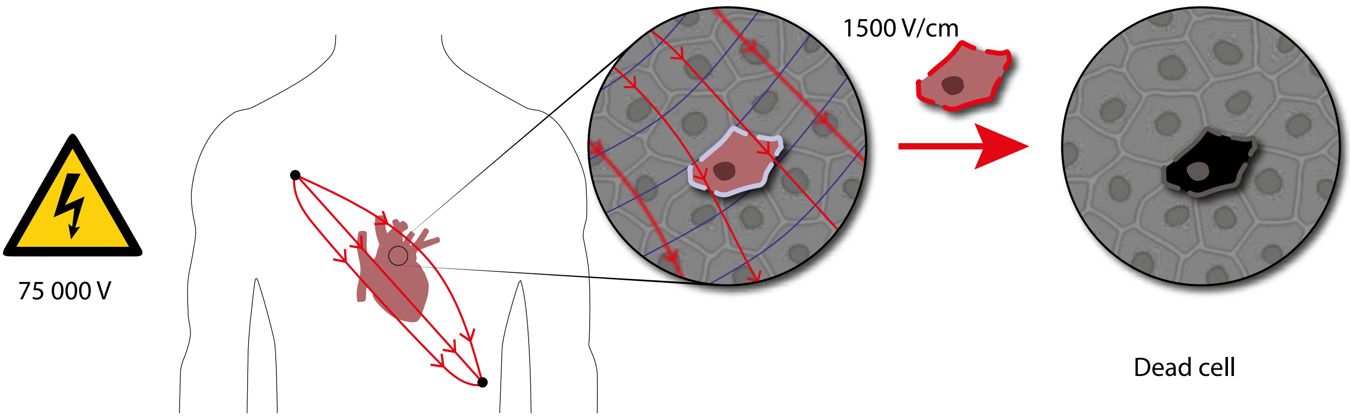


Figure 15: *Irreversible electroporation with a tension of 75 000V.*

SUMMARY

For a safe and efficient defibrillation, it is necessary to:

- Excite a maximum number of cells by applying a sufficient current
- Provide the least energy possible to the patient by adapting the duration of the shock to the chronaxie time
- Avoid irreversible electroporation by adjusting (in amplitude and duration) the value of the voltage gradient applied.
- Ensure a constant total energy received during defibrillation shock, regardless of the patient's impedance, by using an impedance compensation method.
- Limit the post-shock silence period by applying a biphasic waveform.

SCHILLER MULTIPULSE BIOWAVE®

Most old defibrillators use monophasic defibrillation waveforms. However, today many studies showed that the use of biphasic waveforms is more efficient. It has been validated by both AHA (American Heart Association) and ERC (European Resuscitation Council).

SCHILLER made the choice to use a technology named Multipulse Biowave which is a pulsed biphasic truncated exponential defibrillation waveform[7]. This technolgy offers a soft, efficient and intelligent defibrillation.

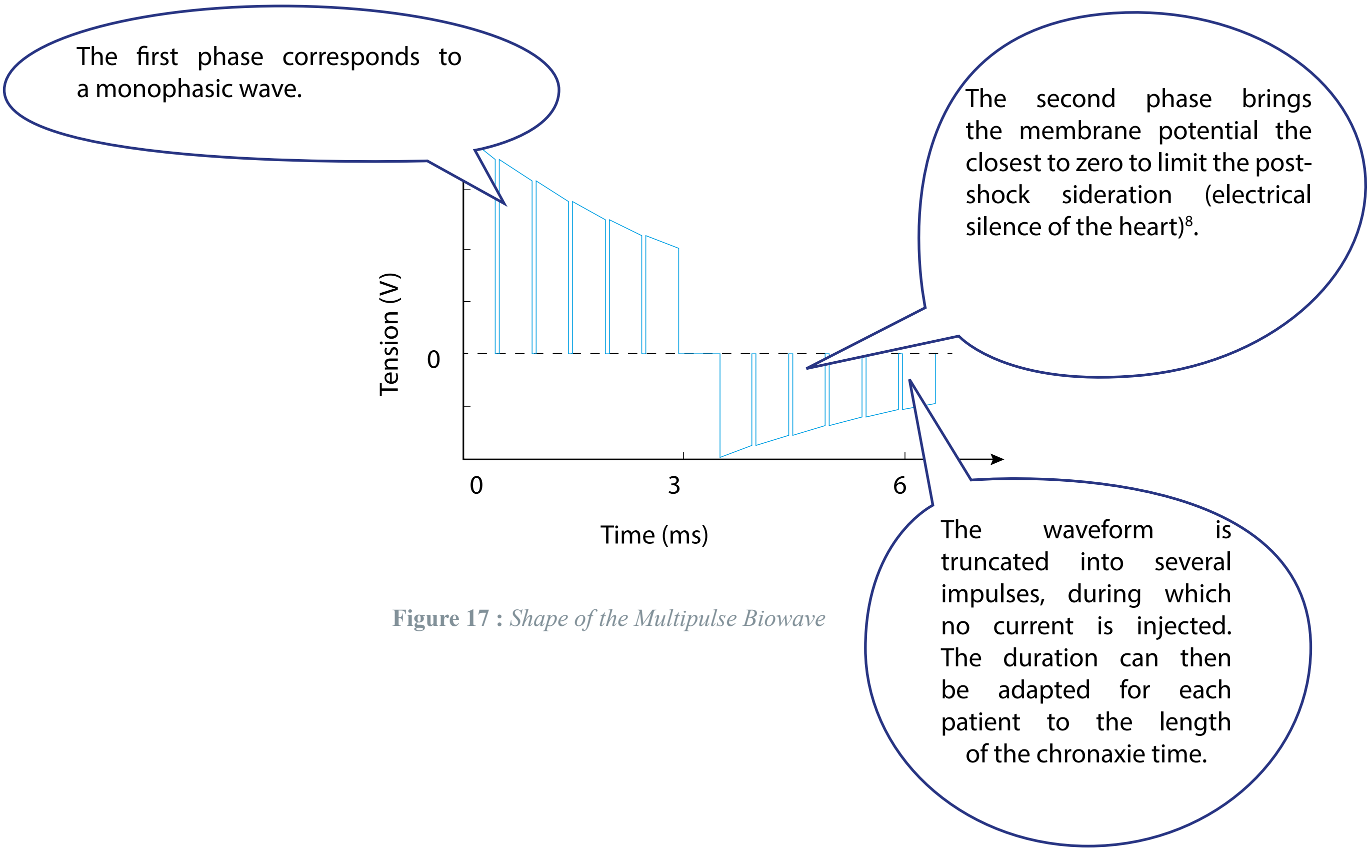


Figure 17 : *Shape of the Multipulse Biowave*

According to a study made on 102 patients[9], 95 % of the patients have an impedance between 45 and 135 Ohms. From this intervall, and in order to maintain an almost constant energy during shock, the duration of the first phase of our waveform is between 3 and 6 ms.

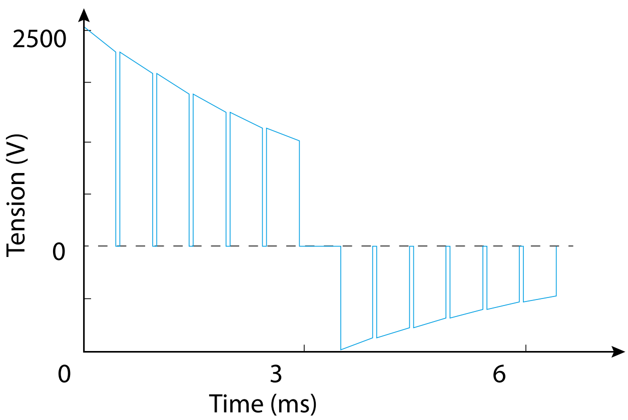


Figure 18: *Waveform for an impedance of 45 Ohms.*

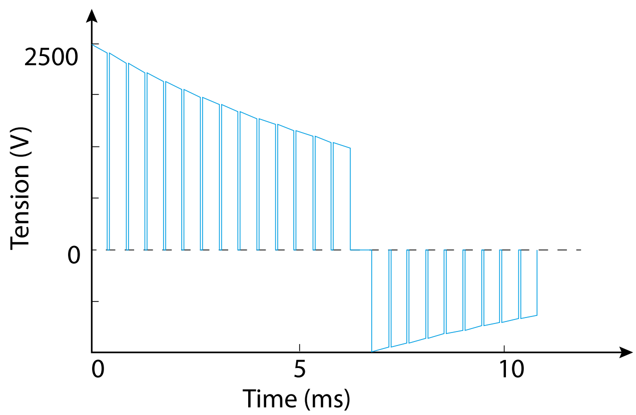


Figure 19: *Waveform for an impedance of 135 Ohms.*

According to a study conducted on patients having atrial fibrillations [10], the defibrillation waveform Multipulse Biowave® have the advantage of reducing post-shock complications.

THE ADVANTAGES OF SCHILLER'S TECHNOLOGY

Energy efficiency

Most defibrillators are equipped with technologies limitting energy variations caused by the patient impedance. The energy can be dissipated in resistors. However, SCHILLER made the choice of energy efficiency by delivering most of the energy stored in its low capacitance condensators.

A too high energy level is useless and dangerous[11]

SCHILLER limits the energy available on its defibrillators on purpose, and they are as efficient as other devices that embeds a more energetic waveform (360J like on old monophasic defibrillators). These high energy defibrillators are not more efficient, because the duration of the shock is further from the chronaxie time.

These advantages allow SCHILLER to produce the most compact defibrillators on the market (figures 20 and 21) while ensuring efficiency and safety in accordance with the international norms.[12 13]

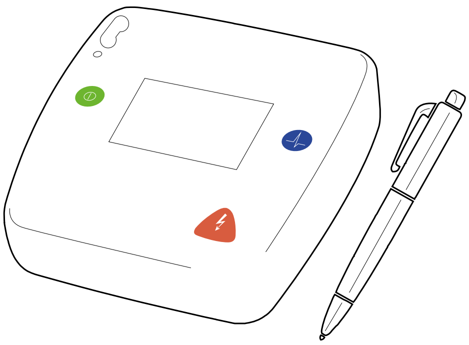


Figure 20: *FRED® Easyport, The most compact defibrillator in the world*

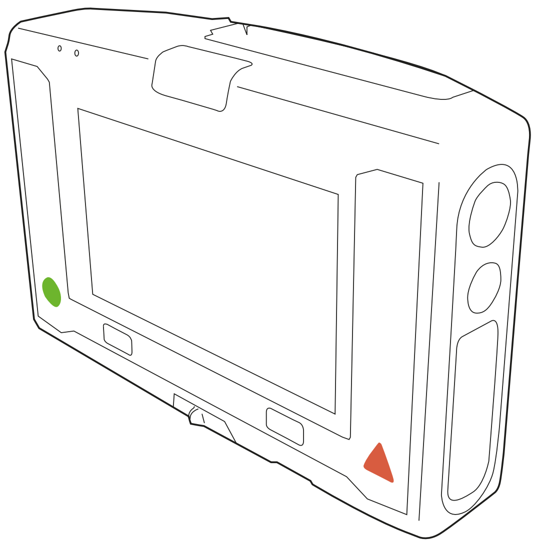


Figure 21: *DEFIGARD® Touch 7, The most compact defibrillator/monitor in the world*

It is common to compare defibrillators with the maximum energy that they are able to deliver (360J or 200J ?). But, it's indeed the current that defibrillates, not the energy !

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[8] D. Snyder et al., “Biphasic Defibrillation: Peak Current Predicts Survival While Higher Energy and Average Current Increase Myocardial Dysfunction”, Resuscitation, vol.64, (2005) : 63-69

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[13] C.Lejeune et al., “Value of Pulsed Biphasic Defibrillation Shocks for the Treatment of Out-of-Hospital Cardiac Arrest”, Journal of Interventional Cardiac Electrophysiology, vol.22, no. 1, (2008) : 83

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