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## Defibrillation Threshold of Gurvich-Venin Biphasic Current Waveform in Swine

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### Introduction

Professor Naum Gurvich who has entered a biphasic waveform was one of pioneers of defibrillation. In 1968 engineers Venin et al. suggested an electronic scheme for a biphasic quasi-sinusoidal impulse with given pattern of half-waves. Experimental research on animal models demonstrated that an impulse with equal half-waves (called symmetric biphasic quasi-sinusoidal impulse) was less effective than a monophasic impulse. An interdisciplinary team of doctors from Institute of General Reanimatology — Gurvich, Tabak, Bogushevich (Moscow, Russia) and engineers from Institute of Radio Electronic Medical Apparatus — Venin, Pasechik, Baluashilli (Lviv, Ukraine) worked out the concept of biphasic asymmetric quasi-sinusoidal defibrillating impulse. Effectiveness increased almost twice as a result of summing asymmetric parts and it was named the Gurvich-Venin waveform. In 1970 the USSR began the industrial production of external defibrillators DI-03 (Fig. 1) and DKI-01, generating a such waveform [1, 3, 9].

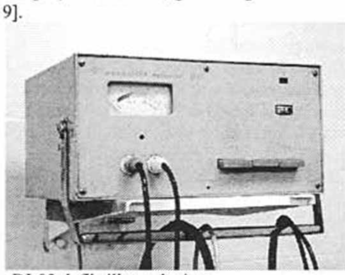

Fig. 1: DI-03 defibrillator device.

The modern generation of external defibrillators automatically adjusts defibrillation waveform based on patient impedance measurement. Two different impedance compensation methods, namely current-based and duration-based techniques are used in current commercial defibrillators [7]. Original external defibrillators with Gurvich-Venin waveform had no such methods yet.

In article results of designing and testing in experiments on swine-models of the Gurvich-Venin current waveform are presented. Motivation and background of this work consist in the following:

(a) Gurvich-Venin waveform is effective for external defibrillation;

(b) Gurvich-Venin waveform formation is perspective to use digital technologies [2];

(c) "Although energy levels are selected for defibrillation, it is the transmyocardial current flow that achieves defibrillation. Current correlates well with successful defibrillation and cardioversion. The optimal current for defibrillation using a monophasic waveform is in the range of 30-40 A. Indirect evidence from measurements during cardioversion for atrial fibrillation suggests that the current during defibrillation using biphasic waveforms is in the range of 15-20 A. Future technology may enable defibrillators to discharge according to transthoracic current: a strategy that may lead to greater consistency in shock success. Peak current amplitude, average current and phase duration all need to be studied to determine optimal values, and manufactures are encouraged to explore further this move from energy-based to current-based defibrillation." [4,8];

(d) For transthoracic impedances greater than average, the current-based compensation method is more effective than the duration-based compensation one [7].

### Material and Methods

#### Gurvich's current waveform formation

Bloc-diagram of defibrillation waveform-shaping unit by digital signal processor (DSP) is presented on Fig. 2. The unit contains several independently controlled power cells with reversible polarity, stacked in series to provide maximum voltage on the output up to 3600 V. Voltage and current sensors measure patient voltage and current. Smoothing inductor prevents rapid current changes during regulations. DSP controls and operates of the power cells. Unlike the preceding technology, all feedback control actions calculate in digital domain.

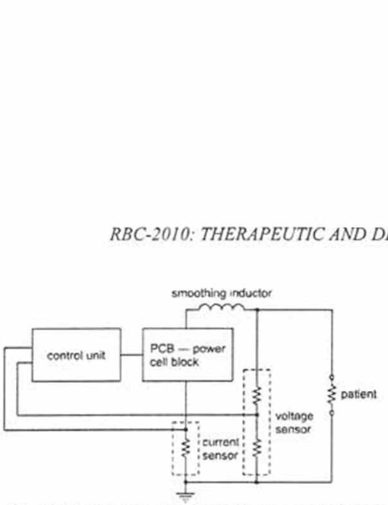


Fig. 2: Block-diagram of defibrillation pulse-shaping unit by DSP.

During the delivery of impulse the control unit continuously samples the signals from current and voltage sensors and makes analog-to-digital conversion. Based on sampled values DSP calculates difference between the actual and reference waveforms and takes required control action to the power cells, by switching power cells on and off. Current waveform control method is implemented. Thus, Gurvich-Venin current waveform is constant and does not depend from impedance changes during delivery the defibrillation shock.

Comparison of characteristics Gurvich-Venin biphasic waveform (GBW) with rectilinear biphasic waveform (RBW), current-based technique, and biphasic truncated exponential waveform (BTE), duration-based technique is presented on Fig. 3.

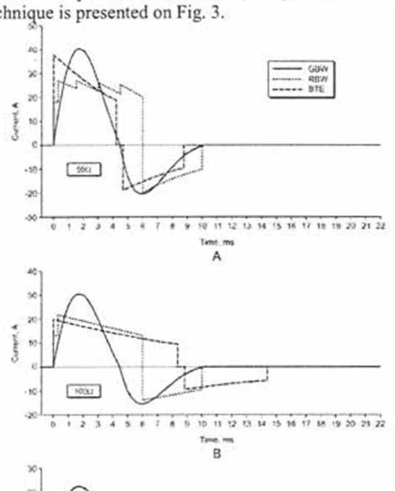


Fig. 3: Comparison of GBW with RBW and BTE at different load impedance (A) 50 Ohm, (B) 100 Ohm and (C) 150 Ohm

**Automated unit for experimental researches on animal-models**

Automated unit for experimental researches of efficiency external defibrillators /cardioverters at various waveforms and parameters of electrical pulses, real-time measuring of transthoracic electrical impedance during external defibrillation is presented on Fig. 4. There are module for heart fibrillation of animals, module for defibrillation/cardiversion procedures and module for monitoring of physiological parameters of the animals. The module for monitoring of physiological parameters of the animals contains display (monitor), invasive pressure sensors, ECG sensors, multichannel universal analog-to- digital converters, personal computer and uninterrupted power source. Energy divider provides a rough choice of energy value for defibrillation. Voltage and current sensors detects the real electrical parameters on animal.

This unit was approved by the Institute of Transplantology and Artificial Organs at Animal Laboratory.

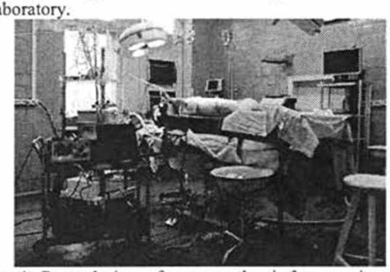

Fig. 4: General view of automated unit for experimental researches on animal-models.

**Animal preparation**

Domestic farm swine (33-62 kg) were sedated and anaesthetized initially with intramuscular injection of relanium (0.5 mg/kg) and xylazine (2.0-3.0 mg/kg); intravenously — thiopental sodium (2.5 %) by 10-15 mg/kg/hour. Infusion therapy included physiological solution. Each animal was intubated, restrained in dorsal recumbency, and mechanically ventilated with a mixture of room air and oxygen. Arterial blood gas values, electrolyte levels were determined every 30 min and maintained within the normal range for the duration of the experiment. Adhesive electrode pads were applied to the shaved cutaneous surfaces of the left and right lateral thorax, in position approximating the anterior-lateral placement used for human defibrillation. Fibrillation was initiated by alternating current (amplitude — 20 V, frequency — 50 Hz ) through electrodes for defibrillation. Duration of fibrillation was 20 s.

**Determination of defibrillation threshold**

Defibrillation thresholds (DFT) compared among GBW, designed by Department of Biomedical Systems of Moscow Institute of Electronic Technology, RBW — ZOLL E Series, BTE1 — Physio-Control LIFEPAK 12, BTE2 — Philips HeartStart MRx. For each experience, special values of additional resistors, series and parallel connected to animal was selected. Thus loading impedance was 100 Ohm for defibrillator output. Step-up-down method was used for determination of DFT [6]. Energy step was 5 J in average. DFT defined not less than three times in each experience. Twenty sets of fibrillation-defibrillation trials were performed in each animal. The average value of transthoraric impedance was calculated.

## Results

### Dynamics of animal impedance

Typical curve for dependence of animal impedance on electrical current through animal is presented on Fig. 5. At an initial stage of pulse the impedance decreases (from point 1 to point 2). Further the impedance continues to decrease, and then begins increases (from point 2 to point 3). Impedance again decreases in a point 4. In the end of pulse the impedance increases again (from point 5 to point 6).

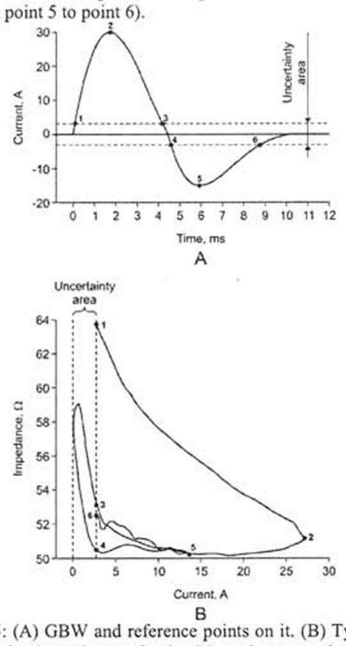


Fig. 5: (A) GBW and reference points on it. (B) Typical curve for dependence of animal impedance on electrical current through animal during shock of GBW.

Thus, there is a nonlinear dependence between animal impedance and electrical current through animal. On this dependence there are sites of monotonous and nonmonotonic (from point 4 to point 6) change of impedance. The impedance is close for points 3 and 6, but differs for points 3, 6 and 4. The animal impedance is virtually a pure resistance.

### Comparison of defibrillation thresholds

Comparison of DFT for GBW and BTE is presented in Table 1. Average value of DFT is (77.6 ± 15.1) J for GBW; (109.7 ± 12.1) J for BTE1; (104.1 ± 14.5) J for BTE2. Comparison of DFT for GBW and RBW is presented in Table 2. Average value of DFT is (83.5 ± 16.0) J for GBW; (89.0 ± 16.0) J for RBW. Animal number, weight and average transthoraric impedance are presented in tables also.

Table 1: DFT values for GBW, BTE1 and BTE2

| Animal | | GBW | | BTE1 | | BTE2 | |
|---|---|---|---|---|---|---|---|
| Number | Weight, kg | DFT, J | Transthoracic impedance, | DFT, J | Transthoracic impedance, | DFT, J | Transthoracic impedance, |
| 1 | 35 | 100 | 48 | 115 | 48 | 111 | 44 |
| 2 | 35 | 93 | 50 | 111 | 48 | 107 | 42 |
| 3 | 49 | 60 | 48 | 112 | 52 | 106 | 47 |
| 4 | 47 | 64 | 47 | 89 | 45 | 79 | 44 |
| 5 | 49 | 73 | 41 | 109 | 47 | 92 | 41 |
| 6 | 55 | 84 | 44 | 129 | 48 | 124 | 44 |
| 7 | 62 | 69 | 47 | 103 | 49 | 110 | 45 |

Table 2: DFT values for GBW and RBW

| Animal | | GBW | | RBW | |
|---|---|---|---|---|---|
| Number | Weight, kg | DFT, J | Transthoracic impedance, | DFT, J | Transthoracic impedance, |
| 1 | 40 | 100 | 58 | 100 | 54 |
| 2 | 35 | 82 | 61 | 88 | 61 |
| 3 | 45 | 103 | 58 | 122 | 51 |
| 4 | 42 | 70 | 51 | 81 | 52 |
| 5 | 52 | 120 | 66 | 104 | 62 |
| 6 | 52 | 86 | 56 | 98 | 54 |
| 7 | 44 | 109 | 63 | 103 | 59 |
| 8 | 44 | 90 | 58 | 102 | 57 |
| 9 | 44 | 72 | 50 | 73 | 51 |
| 10 | 47 | 89 | 62 | 81 | 66 |
| 11 | 47 | 64 | 58 | 62 | 56 |
| 12 | 33 | 82 | 77 | 92 | 73 |
| 13 | 33 | 65 | 70 | 76 | 71 |
| 14 | 57 | 69 | 63 | 60 | 64 |
| 15 | 60 | 73 | 69 | 81 | 67 |
| 16 | 55 | 84 | 44 | 105 | 43 |
| 17 | 60 | 69 | 47 | 87 | 45 |
| 18 | 60 | 76 | 45 | 87 | 45 |

**Discussion**

There is a nontrivial, nonlinear dependence between animal impedance and electrical current through animal. Such dependence is similar the results of Hatib et al. [5]. The current-based compensation technique was more effective than the duration-based compensation technique. Such result is similar of conclusion of Li et al. [7]. The difference between GBW and RBW is small in presented experiments.

DSP is very convenient for defibrillation pulse-shaping based on feedback loop with load impedance. Such technology is realized in imPulse (Fig. 6) and imPulse PRO (Fig. 7) automatic external defibrillators (AEDs) that designed by Department of Biomedical Systems of Moscow Institute of Electronic Technology.

Fig. 6: imPulse AED for public use.

Fig. 7: imPulse PRO AED for professional use (with color LCD screen, semi-automatic, synchronous manual, asynchronous manual and ECG monitoring operation mode).

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## The Development of Technology to Increase the Pain Barrier by Ultrasonic

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**Introduction**

Currently the problem of increasing the pain barrier has become acute in many fields of medicine. Abating strong pains permits to relieve a patient's negative attitude to different injections recommended for treatment during intensive care (after surgical operations during a rehabilitation period of grown-ups and