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Why quasi-sinusoidal biphasic Gurvich pulse?



N.L. Gurvich during defibrillation experiment.
Moscow, USSR, not later than in 1965 (in the lower
right corner — the first commercial DC defibrillator
ID-1-VEI in the world)

Background

Naum Lazarevich Gurvich (1905-1981) — the Soviet scientist, the founder of practical DC cardiac defibrillation, author of two monographs on cardiac defibrillation, «Cardiac fibrillation and defibrillation», 1957 [1], and «Basic principles of cardiac defibrillation», 1975 [2].

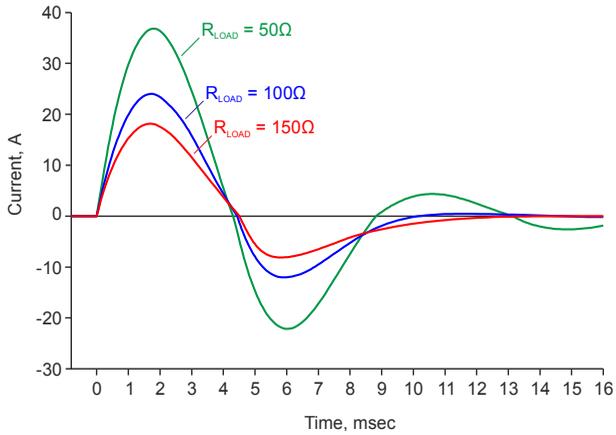
Production of the first commercial DC defibrillator constructed by N.L. Gurvich later named as ID-1-VEI [3], which was initially aimed at defibrillation without chest opening during emergency care in case of electrocutions started in the USSR in 1952. Discharge LC-circuit of defibrillator ID-1-VEI generated monopolar sinusoidal pulse.

Further investigations conducted by N.L. Gurvich revealed the advantage of biphasic defibrillation pulse in comparison with monopolar one. It resulted in development of the first commercial defibrillator in the world with biphasic pulse form DI-03, batch production started in 1972 [4, 5]. Defibrillator pulse DI-03 is known under the names of quasi-sinusoidal biphasic pulse, Gurvich pulse and Gurvich–Venin pulse (Igor Viktorovich Venin is the engineer under whose supervision DI-03 defibrillator as well as a number of other defibrillators were developed).

Discharge LC-circuit which was dampened by resistor connected through diode for ensuring correlation of first and second pulse phases amplitudes was also used in defibrillator. Due to discharge circuit defibrillation pulse duration did not actually depend on interelectrode impedance.

The first defibrillator for external defibrillation with biphasic pulse for in the USA, ForeRunner™, was produced in 1996, 24 years later than DI-03 [6].

Defibrillator DI-03 had dimensions of 423×330×243 mm and weight of 22 kgs. Power was supplied by alternate current network 220/127V either by autonomous rechargeable power supply unit BP-03 with dimensions of 188×355×245 mm and weight of 12 kgs. Defibrillator was not equipped with ECG monitor.



DI-03 defibrillator pulse provided highest energy dose 200J (quasi-sinusoidal biphasic Gurvich pulse)



DI-03 DC defibrillator

Experimentation on animals

The advantage of pulse similar to Gurvich pulse compared with monopolar pulse was first proved in the USSR during the experiment on dogs in 1967 [7]. Defibrillation current amplitude threshold value for biphasic pulse (6.6A) was significantly lower than that of monopolar (9.6A).

Advantage of quasi-sinusoidal biphasic pulse over critically damped monopolar pulse was shown in the USA in 1988 [8]. Efficiency of critically damped monopolar pulse in the experiment on calves of 100 kg weight constituted 37% provided average released energy 206J while efficiency of quasi-sinusoidal biphasic Gurvich pulse was 88% under average released energy of 201J.

Comparison of two biphasic pulses — truncated exponential and quasi-sinusoidal Gurvich pulse was first made during experiment on dogs in the study in 1998 [9]. Energy threshold provided 50% defibrillation success of truncated exponential pulse in the experiment was 25% higher than that of Gurvich pulse. It was also specified that defibrillation energy threshold of Gurvich pulse does not actually change in case of fibrillation period increase while such period grows considerable in case of critically dampened monopolar pulse.

Experiments conducted recently in Russian on high-resistance model of swines showed advantage of biphasic quasi-sinusoidal Gurvich pulse over two types of biphasic truncated exponential pulse and over biphasic rectilinear pulse [11-12].

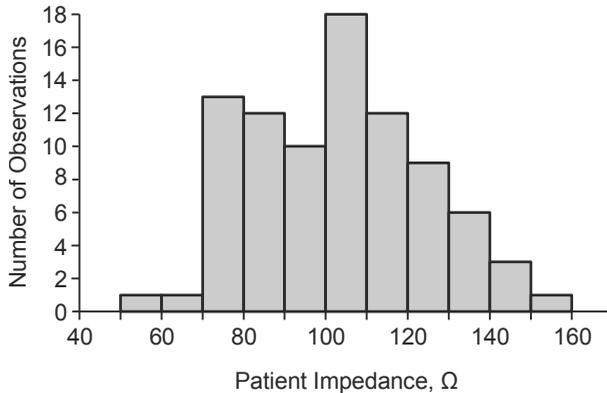
Two aspects ensuring advantage of Gurvich pulse form

1. *Pulse form independence from interelectrode impedance value*

Term “energy” includes such parameters like capacity and voltage with missing of a key role of an impulse time duration, nevertheless time is a main factor in detection of optimal electric stimulation on the heart. [13]

It is the current that defibrillates, not the energy, so it is important to maintain the same defibrillation pulse duration for patients with high chest impedance as for patients with low impedance. Pulse form maintenance ensures minimization of defibrillation energy threshold value provided high chest impedance. Research has shown that in case of usage of large pad electrodes in standard anteriolateral position average value of patients constitutes $103 \pm 21 \Omega$ 1 minute after electrodes application with range of values from 59Ω to 151Ω [14]. Gurvich pulse form does not depend on patient chest impedance. The same property is characteristic of biphasic

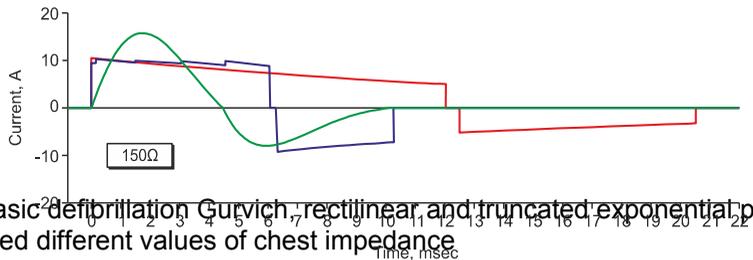
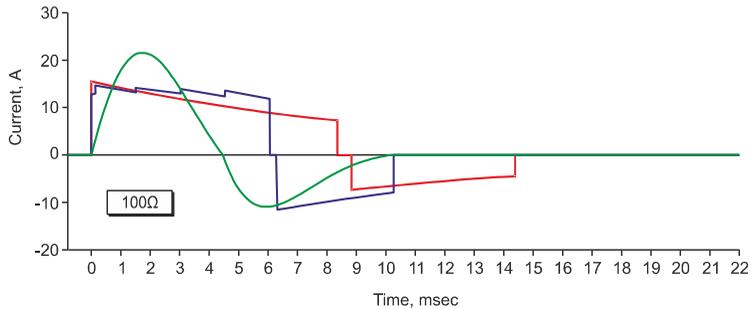
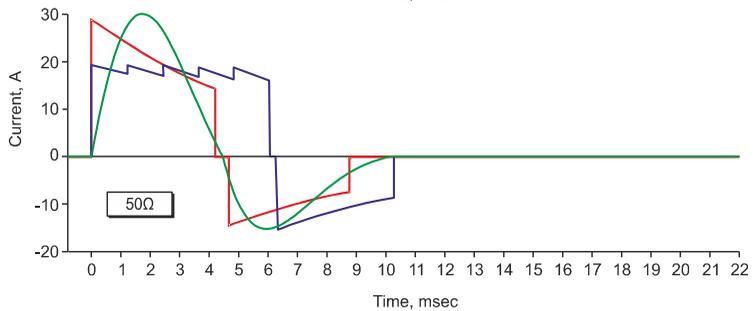
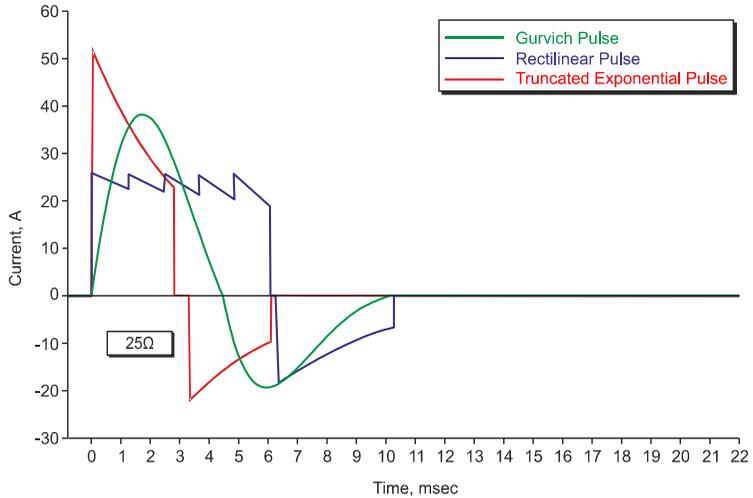
rectilinear pulse (Rectilinear Biphasic) used in defibrillators of ZOLL Medical Corporation, high efficiency of which is confirmed by clinical evidence. For instance, in the study [15] ventricular fibrillation of 94 patients was eliminated by the first discharge of biphasic rectilinear pulse with energy dose of 120J in 87.8% of cases.



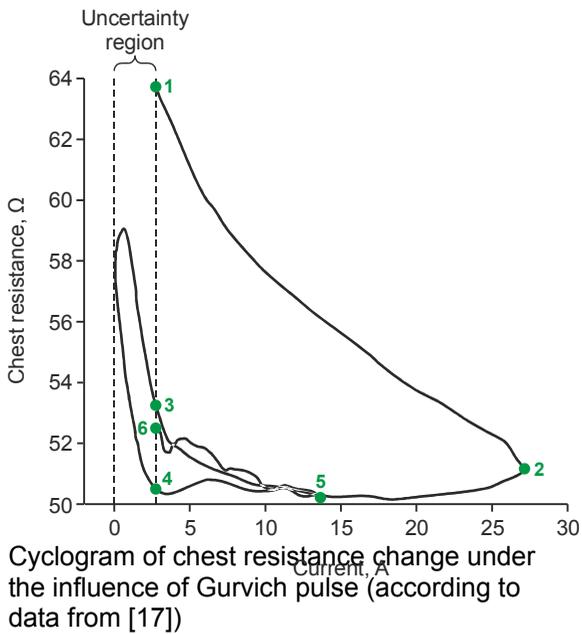
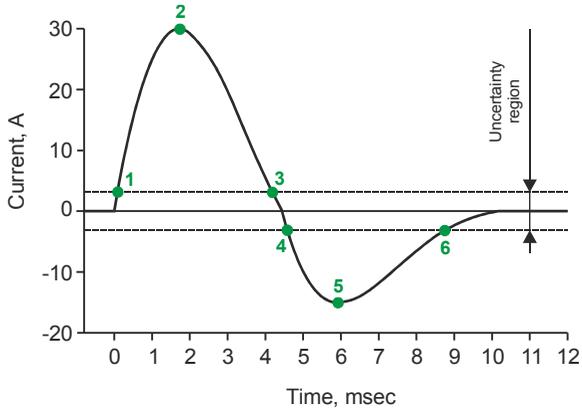
Distribution histogram of values of patient impedance within 1 minute after application of large pad electrodes in standard anteriolateral position (according to data from [14])

2. Rounded pulse rise promotes reduction of threshold energy during external defibrillation

As shown in the study [16] rounding of the form of biphasic truncated exponential defibrillation pulse decreases its threshold energy. Possible explanation of this fact was obtained during studying the change of chest resistance within the Gurvich pulse action [17]. It was established that chest resistance decreases by 16% in the average (range from 10% to 22%) and further changes insignificantly within the first two pulse milliseconds by the moment of its peak value achievement. This ensures reduction of defibrillation energy threshold due to defibrillation peak current increase.



Biphasic defibrillation Gurvich, rectilinear and truncated exponential pulses provided different values of chest impedance



Cyclogram of chest resistance change under the influence of Gurvich pulse (according to data from [17])

Results of Gurvich pulse clinical use

Defibrillators with Gurvich pulse were mainly used in the USSR and in Russia. However the data about efficiency comparison of monopolar Edmark pulse with biphasic quasi-sinusoidal Gurvich pulse during cardioversion in the clinic were published in 1995 in the USA [18]. The first discharge of Edmark pulse with released energy of 215 ± 11 J enabled eliminating arrhythmia in 85.2% of cases while the first discharge of Gurvich pulse with released energy of 171 ± 11 J was helpful in 97.6% of cases.

Results of Gurvich pulse clinical use in Russia are given in studies [19-32]. The table from [32], is given below stating that 100% defibrillation efficiency of Gurvich pulse is provided by energy dose not more than 200 J and in case of discharge energy up to 115J ventricular fibrillation is eliminated in 86% of cases. For comparison: biphasic rectilinear pulse eliminates ventricular fibrillation by first discharge with energy dose of 120J in 87.8% of cases [15].

Inhospital cardiac defibrillation: total efficiency of biphasic quasi-sinusoidal pulse depending on shock energy during elimination of recurrent primary and secondary ventricular fibrillation (VF)* (paddles diameter 12 cm)

Shock energy, J	Efficiency, %		
	Primary VF	Secondary VF	Primary and secondary VF
≤ 65	79	52	62
≤ 90	100	57	73
≤ 115	—	76	86
≤ 150	—	88	94
≤ 200	—	100	100

* recrudescence course of VF was observed for 29% patients with primary and 47% of patients with secondary VF; duration of 1 VF episode constituted from 0,5 to 6 min.; provided consistent recrudescence or refractory course total duration of VF was within 6-20 min.; up to 4-6 shocks were applied for elimination of 1 episode of refractory VF.

Automatic external defibrillators with Gurvich pulse

Automatic external defibrillators generating biphasic quasi-sinusoidal Gurvich pulse imPulse, imPulse LCD and imPulse PRO have a size of 84×225×240 mm and weight with battery supply 2.5 kgs. For comparison, total DI-03 defibrillator weight with power supply unit BP-03 constituted 34 kgs [33].



imPulse



imPulse LCD



imPulse PRO

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JSC Zelenograd Innovation-Technology Center of Medical Equipment

124498, Russian Federation, Moscow, Zelenograd, road 4806, 5/23

Mailing address: 124498, Russian Federation, Moscow, Zelenograd,
PO box 56, JSC ZITC-MT

Tel.: +7 499 720 89 86 Fax: +7 499 720 89 85

E-mail: info@zitc-mt.ru

www.zitc-mt.ru