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INITIAL DYNAMICS OF THE EKG DURING AN ELECTRICAL DEFIBRILLATION
OF THE HEART

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Translation of "Pochatkova dinamika EKG pri elektrychniy
defibrylyatsii sertsya," Fiziologichnyy Zhurnal Akademii
Nauk Ukrains'koy RSR, Vol.15, No. 3, 1969, pp. 322-327

(NASA-TM-76002) INITIAL DYNAMICS OF THE EKG
DURING AN ELECTRICAL DEFIBRILLATION OF THE
HEART (National Aeronautics and Space
Administration) 12 p HC A02/MF A01 CSCL 06P

N80-21019

Unclas
G3/52 46764

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

APRIL 1980



INITIAL DYNAMICS OF THE EKG DURING AN ELECTRICAL DEFIBRILLATION OF THE HEART

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There are no data in the literature on the dynamics of the EKG immediately after application of a defibrillating discharge, since recordings of the electrical activity of the heart begin no sooner than a few seconds after passage of a powerful (5-15 A) current through the target [1, 5].

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Also, the transition process in the development of fibrillation after an electrical trauma has not been studied, and there is no knowledge of the effect of a subthreshold electrical stimulus on the development of fibrillation. These delicate questions are especially important for the electrophysiological interpretation of many authors [2, 3, 5, 8] of the positive effect of repeated defibrillation, in those cases when single trials fail.

In this study, cardiograms were recorded before and 0.04-0.06 sec after application of a defibrillating discharge (in all figures, the time of the discharge is designated by a dot).

Method

In the studies, an experimental defibrillator [7] and a system of automatic devices were used, which permitted the use of these operations: 1. closing the "damping" switch of the electrocardiograph; 2. switching on the recording electrodes and closing the equivalent arms of the electrocardiograph input switches; 3. connection of the defibrillation electrodes to the defibrillator; 4. giving commands to turn on the defibrillator; 5. switching off the defibrillator electrodes from the target; 6. restoring the switches of the recording electrodes of the electrocardiograph; 7. switching on the "damper."

* Numbers in the margin indicate pagination in the foreign text.

In this case, a recording interval of 0.1-0.2 sec was recorded on the EKG (Fig. 1a).

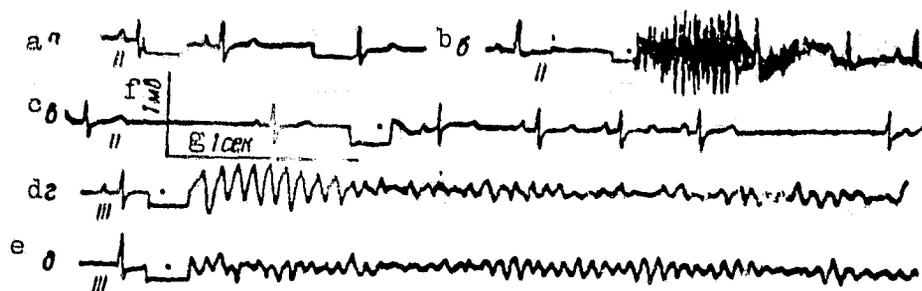


Fig. 1. Method of study and examples of fibrillation: a. interruption of record in fatigue of synchronizer, b. artefact of muscle tremor after passage of pulse; c. example of effect of pulse on normally functioning heart (65% of threshold current strength); d. fibrillation through series of decreasing large amplitude oscillations (experiment 9; 58% of threshold current strength); e. example of fibrillation through irregular low amplitude oscillations (experiment 9; 80% of threshold current strength). Key: f. 1 mV g. 1 sec

The studies were conducted on 11 random bred dogs weighing from 6 to 23 kg. The animals were under morphine anesthesia, at a dose of 0.5 ml of 1% morphine solution per kg of weight.

The electrocardiograms were recorded with a EKPS-Ch instrument, the femoral artery pressure was monitored kymographically and the respiration, by means of a pneumatic cuff.

Since muscle tremor developed after passage of the defibrillating stimulus, which masks the electrocardiogram (Fig. 1b), the skeletal muscles were disengaged with listenon, and the study was conducted with artificial respiration. In this case, noticeable artefacts were absent (Fig 1c).

Fibrillation was induced with 127 V alternating current, which was passed through electrodes inserted under the skin of the right front and left rear paws for a period of 2 sec.

In this case, the start of fibrillation was not successfully recorded, despite the clear operation of the synchronization system and

cut off of the stimulating current in the zero phase, since the bioelectric complexes were masked by a slowly (over 4-8 sec) decreasing potential, which evidently is connected with electrochemical shifts in the tissues, caused by the persistent effect of the alternating current.

Records of the initial fibrillation were obtained by stimulation of the heart with an electrical stimulus in the "early" phase of the electrocardiographic cycle, the rising arm and peak of the T spike.

Defibrillation was performed with 0.04 sec long alternating current, which was made up of the symmetrical first two and decreasing third and fourth half waves. The pulse of this configuration was well recommended in studies conducted earlier. /323

The defibrillation threshold was produced 10-20 sec after the electrical trauma, by stepwise presentation of stimuli of increasing magnitude. The strength of the current was recorded in this case.

Fibrillation of the hearts of the same animals was induced repeatedly, with 15 min intervals between individual electrical trauma.

Results and Discussion

Fibrillation. Basically, only 2 more or less typical variations can be sketched in the dynamics of each fibrillation: 1. large, regular sinusoidal oscillations, which gradually die out and become irregular (Fig. 1d); 2. a small spike process of irregular shape, which differs very little from some types of cardiograms in further development of fibrillation (Fig. 1, 2).

Antagonistic interrelations of the amplitudes of standard leads I and III in the initial fibrillation are presented in Fig. 2a, b. Occasionally, several initial complexes can be observed, which remotely resemble ventricular extrasystoles which, in the opinion of some authors [6], precede the start of fibrillation (Fig. 2, c, d). /325

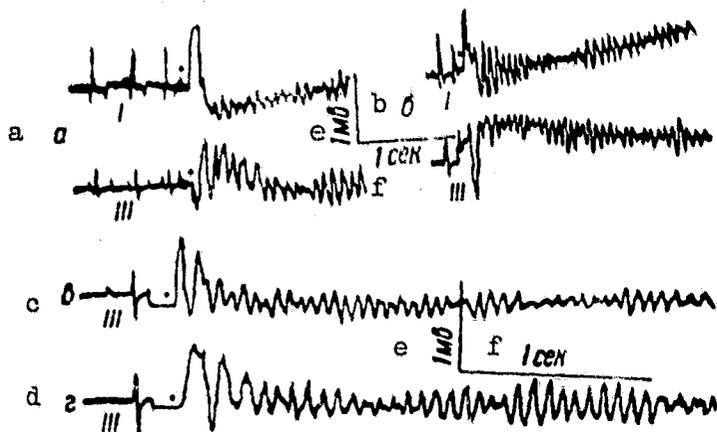


Fig. 2. Fibrillation: a, b. examples of antagonistic relationship of amplitudes of standard leads I and III in fibrillation (experiment 7; a. 41%, b. 80% of threshold current strength); c, d. examples of fibrillation through series of extrasystole like complexes (c. experiment 10, 50% of threshold current strength; d. experiment 11, 58% of threshold current strength).

Key: e. 1 mV f. 1 sec

temporary increase in amplitude of fibrillation, which evidently is connected with an increase in organization of the process, due to synchronous excitation of elements of the myocardium.

The swinging is of varied (from 0.4 to 1.5 sec) duration, and its shape most often resembles a damped sinusoid (Fig. 3, a, b), but it can be irregular (Fig. 3c).

Sometimes, the "swings" are spindle shaped, with the maximum 0.6-0.8 sec after application of the stimulus (Fig. 3d). Nearly always, the closer the pulse to the threshold (value, which causes defibrillation), the greater the amplitude **and** duration of the swing (Fig. 4a), but this is not an unailing rule.

In series of defibrillations with close enough intervals between succeeding stimuli, the "swings" progressively become longer, and renewal of the monorhythm occurs, until the last stimulus "succeeds" in falling in the large amplitude phase of the oscillation provoked by the preceding

This entire part of the study is of a preliminary nature, and it does not permit remote conclusions to be drawn on the genesis of fibrillation by pulsed electrical stimulation in the "early" phase of the cardiac cycle.

Effect of subthreshold pulses on fibrillation dynamics; repeated defibrillation. There was a more regular change in the pattern of the EKG, upon application of subthreshold stimuli to the fibrillating heart. In this case, the "swinging" phenomenon is observed, which consists of a

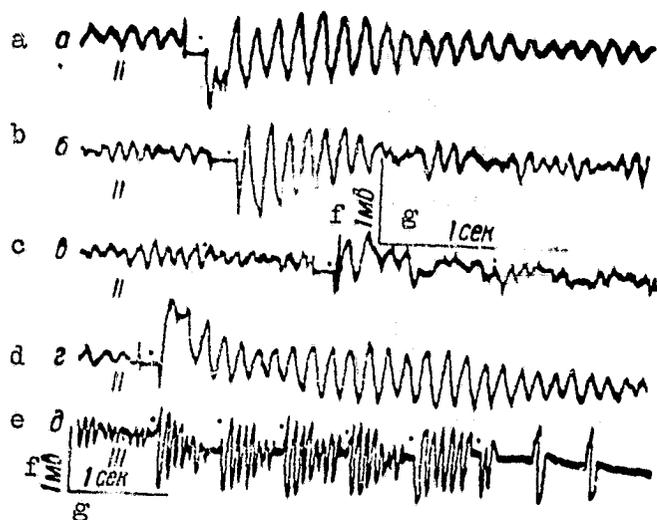


Fig. 3. Diverse "swings" and dynamics of defibrillation series: a, b. examples of decreasing "swings" of different duration, regular shape as result of subthreshold pulses (a. experiment 3, 80% of threshold current strength; b. experiment 4, 60% of threshold current strength); c. irregular shaped "swing" (experiment 2, 80% of threshold current strength); d. spindle like "swing" (experiment 3, 95% of threshold current strength); e. example of progressing "swing" and emergence from fibrillation as result of series of pulses of varied strength (experiment 6).

Key: f. 1 mV g. 1 sec

leads are orthogonal) can be interpreted as a consequence of a return of the master cycle, which forms the basis of the path of movement of the excitation.

The direction of the lines of force of the defibrillation current in our studies was stable (the electrodes were applied to both sides of the thoracic cage in the region of the pericardium). Principally, the configuration of the excitation process with respect to the lines of force always shifts. If subthreshold stimuli are applied at intervals known to be sufficient for the "swinging" effect to begin to play some part, a clear relationship appears, between fibrillation amplitude in the third lead and the effect of this current at the time of passage of the current. Stimuli of the same magnitude, which fall in the phase of

pulse (Fig. 4b). Evidently, the best effect of the paired stimuli is achieved in those cases, when the interval between stimuli varies from 0.2 to 0.3 sec [2]. This interval guarantees that another stimulus will fall in the "swinging" phase caused by the first stimulus. Recommendation of a 0.8-1 sec interval also is not prohibited, if the possibility of spindle like "swinging" is kept in mind.

Dependence of defibrillation threshold on configuration of excitation process in relation to direction of lines of force of defibrillation current.

If a circular theory of fibrillation is maintained, the frequently-observed antagonistic relationships of the EKG amplitudes in leads I and III (for dogs, these



Fig. 4. Effectiveness of current vs. phase of fibrillation process: a. example of progressing "swing" with approach to threshold and emergence from fibrillation through right ventricular complexes, atrio-ventricular automatism and return (not shown in figure) to sinus rhythm through tremor of atrium (experiment 3, 1st pulse 80% of threshold current strength, next pulse 90%, 3rd pulse threshold); b, c. effectiveness of pulse vs. phase of process by lead III (experiment 6, equal strength pulses); d. example of ineffectiveness of 7.2 A pulse in small oscillation phase and emergence from fibrillation upon application of 6.5 A pulse in large oscillation phase (experiment 8).

Key: e. 1 mV f. 1 sec g. a,b,d 1 sec

small, medium and large oscillations, correspondingly, give a rapidly damped "swing," a persistent "swing" and emergence from fibrillation. This is seen easily in the recordings presented in Fig. 4b, c.

Fig. 4d demonstrates the absence of an effect of a 7.2 A pulse in the low amplitude oscillation phase and emergence from fibrillation, as a result of a 6.5 A stimulus in the large oscillation period.

We could not make a quantitative evaluation of the phenomenon described.

Emergence from fibrillation. The patterns of emergence from fibrillation are extremely diverse.

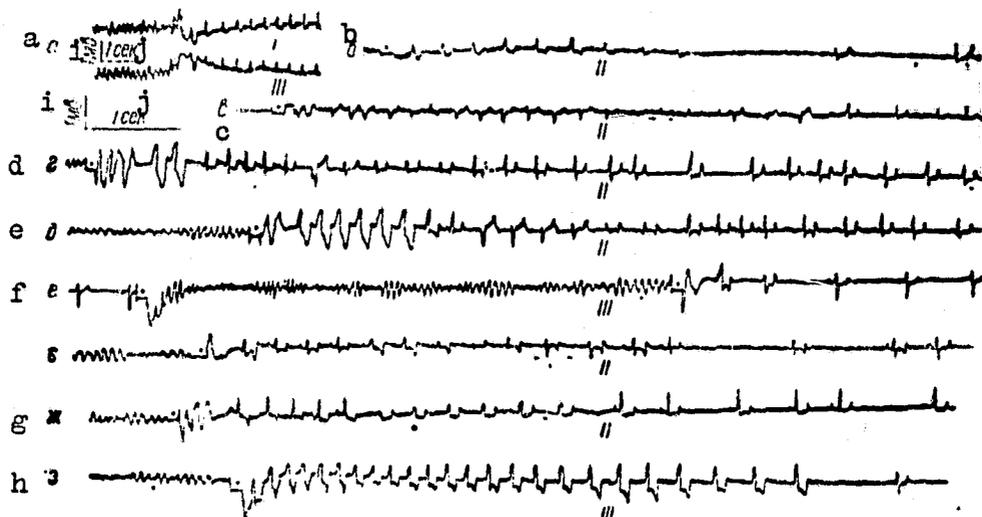


Fig. 5. Examples of emergence from fibrillation: a. right ventricular emergence from fibrillation with rapid appearance of sinus rhythm (experiment 7); b. emergence from fibrillation through left ventricle with movement of pacemaker to area of atrioventricular node (experiment 1); c. emergence through left ventricle (experiment 1); d. e. emergence from fibrillation through "swing" -- left ventricle -- sinus rhythm -- polytopic extrasystole -- nodal rhythm -- sinus rhythm (d. experiment 5; e. experiment 3); f. example of emergence through two right ventricular complexes to sinus rhythm, speed of return to normal of ST interval position, left atrial extrasystole (experiment 10); f. emergence from fibrillation through atypical complex to sinus rhythm with insertion of polytopic extrasystoles; g. emergence from fibrillation through "swing" -- sinus rhythm -- nodal rhythm -- sinus rhythm; h. example of emergence through paroxysmal tachycardia of left ventricular type.

Key: i. 1 mV j. 1 sec

First, there is emergence through "swinging," which can be interpreted successfully as several circular movements of the excitation front through the myocardium (Fig. 4, c, d; 5, d, e, g).

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The primary pacemaker, which conditions the appearance of several ventricular type complexes, likewise, frequently can appear in the myocardium of both the right and left ventricles (Fig. 4 a-c; 5 a-c). As has been noted, the appearance of a monorhythm can precede several sinusoidal complexes but, in many cases, a single pacemaker pulse arises immediately after passage of the defibrillation current. Particularly often, it is not observed in defibrillation with a suprathreshold current. Here, a progressive (over 4-5 cycles) constriction of the QRS complex is characteristic (Fig. 5 b, c).

The atrioventricular pacemaker phase at different levels of this node usually follows the ventricular automatism phase (Fig. 4, 5). At the same time, a displacement of the ST interval to the isolines is observed. The transition from the nodal rhythm to the sinus rhythm lasts different lengths of time, from several seconds to 1-2 min, and it can occur through automatism in the walls of both the left and right atria (Fig. 4d, f). The possibility of sudden appearance of the atrioventricular and even the sinus rhythm is not excluded (Fig. 5a, f).

Sometimes, emergence from fibrillation occurs through paroxysmal tachycardia of the ventricular type (Fig. 5h).

A common feature of the majority of emergences from fibrillation observed is the progressive disturbance of the pacemaker from "bottom to top" and the speed of return to normal of the ST interval, which is connected with the elimination of hypoxia of the myocardium after initial active contractions of the heart.

Quite often, during the nodal and even the sinus rhythm, there have /327 been polytopic extrasystoles and, sometimes, short term flickering arrhythmia has been noted.

Conclusions

1. The initial dynamics of the fibrillation process in stimulation of the heart with an electric current in the "early" phase of the cardiac cycle is not stereotypic.

2. A subthreshold pulse to a fibrillating heart causes the "swinging" phenomenon, which is expressed by an increase in oscillations for 0.4-1.5 sec.

3. In a series of defibrillations, an effect is achieved, at the time when one of the defibrillation pulses occurs in the "swinging" phase caused by the preceding pulse.

4. The defibrillation threshold depends on the configuration of

excitation in the myocardium, with respect to the lines of force of the defibrillation current.

5. The initial dynamics of emergence from fibrillation are extremely diverse, but there is a general tendency towards progressive displacement of the pacemaker from the level of the ventricles to the sinus node, through the phases of atrioventricular and atrial automatism.

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