THE ULTRA-LOW-FREQUENCY ACCELERATION BALLISTOCARDIOGRAM IN RELATION TO AORTIC FLOW AND BLOOD PRESSURE

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The use of ultra-low-frequency acceleration ballistocardiography (BCG) makes available a wide range of information. In order to apply this it is therefore of interest to know the kind of information included in a given complex of the ultra-low-frequency (ULF) acceleration BCG, and a comparison with known physiological methods may broaden our knowledge.

Several studies have shown that a relationship exists between the arterial blood pressure pulse and the IJ-complex of the ULF acceleration BCG. This was indicated by animal experiments,[1-3] and also by analogue computer studies done by Starr and Noordegraaf.[4] Although there is a proved correlation between the ULF acceleration BCG and the pressure pulse, it is a complicated relationship.[4] The purpose of this study was, therefore, a comparison between the ULF acceleration BCG and the time derivatives of the blood pressure as well as the time derivatives of the blood flow.

METHODS

Two groups of experiments were done. Firstly, the ECG, heart sounds, ULF acceleration BCG, blood pressure, aortic flow and the first ($\frac{dF}{dt}$) and second ($\frac{d^2F}{dt^2}$) time-derivatives of aortic flow were recorded simultaneously. In the second group the first 4 functions mentioned above were recorded, while the first ($\frac{dp}{dt}$) and second ($\frac{d^2p}{dt}$) time-derivative of the blood pressure were recorded instead of the aortic flow and the time derivatives.

A Doppler ultrasonic blood flow-meter* was used. A telemetry system can also be used with this flow-meter. The weight and variety of transducer diameters render the chronic use of this flow-meter very convenient. The blood flow and time derivatives of the blood flow are also recorded from the thoracic aorta of goats.

The methods used have been described.[3,5] The first and second time-derivatives of the blood pressure were recorded in the same manner as the first and second time-derivatives of the aortic flow.

Adrenaline, acetylcholine, pitressin and amyl nitrite were administered during different experiments in which the aortic flow was recorded. In the experiments where the time derivatives of the blood pressure were recorded, L-3-methoxy-W-(1-hydroxy-1-phenylisopropylamino)-propiophenone HCl (Ildamen) and propranolol hydrochloride (Inderal) were injected intravenously.

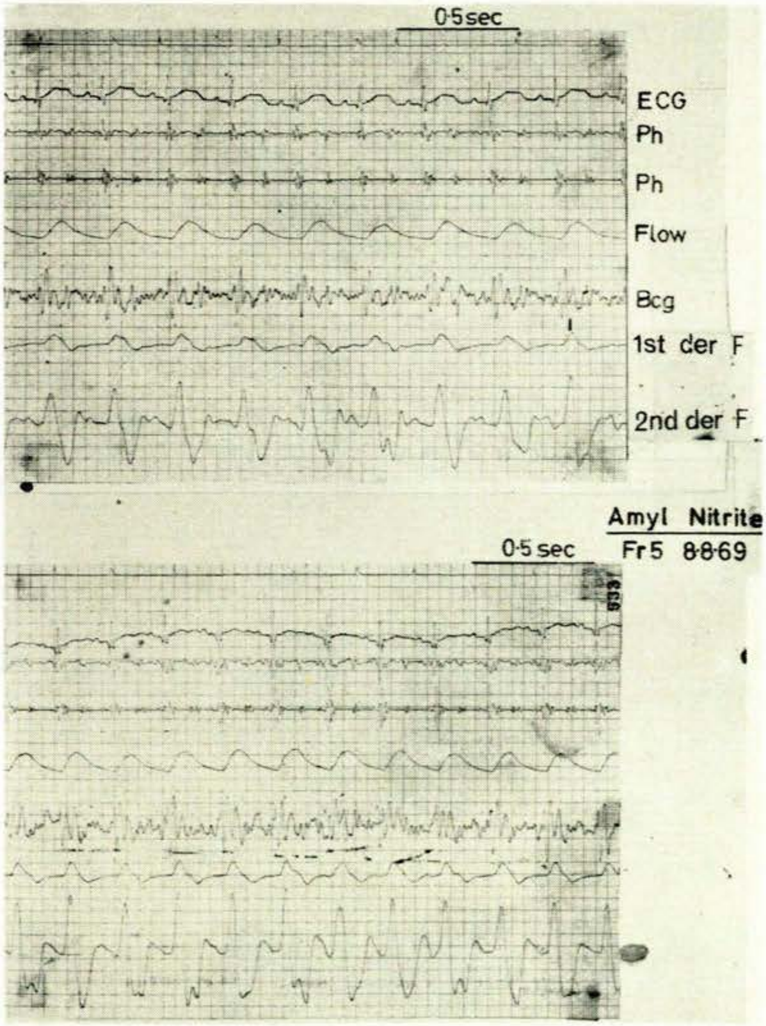

Fig. 1. An example of the influence of amyl nitrite. *Above*: Normal. *Below*: 16 sec. after 1·7 minim / kg. amyl nitrite.

RESULTS

Aortic Flow Experiments

After the administration of 1·7 m/kg. bodyweight of amyl nitrite (during 8 different experiments) the heart rate increased while the Q-time intervals (QH-, QI-, QJ-time as well as the time between Q and positive and negative waves of the time derivatives) shortened. The amplitudes of the ULF acceleration BCG as well as the positive waves of the first and second time-derivatives of the flow increased. The mean percentage increases were: IJ 40%, first time-derivative 23% and the second time-derivative 27%. The amplitude of the blood flow showed different small changes (Fig. 1).

The Q-time intervals decreased while the heart rate increased after the administration of 20 μg./kg. adrenaline. The amplitude of the ULF acceleration BCG and second time-derivative of the flow increased (Fig. 2).

*Manufactured by Ward Associates, California, USA.

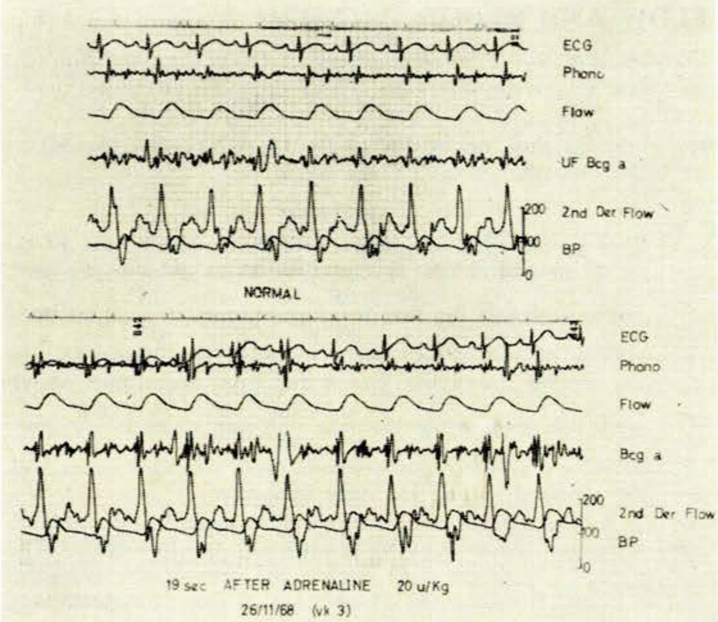

Fig. 2. An example of the influence of adrenaline.

During 5 experiments 1·9 IU/kg. pitressin were administered. A decreased heart frequency and an increase in the Q-time intervals were noted. The following amplitudes showed a decrease: HI- and IJ-wave of the ULF acceleration BCG (mean 39% and 40·1% respectively), the blood flow (mean 57·7%), the first time-derivative (mean 56·8%) and the second time-derivative (mean 33·6%) of the blood flow (Fig. 3).

The amplitudes of the ULF acceleration BCG and the first and second time-derivatives of the flow decreased after the administration of 3 μg./kg. acetylcholine, while Q-time intervals increased. About one minute after the administration of acetylcholine a closer correlation could be seen between the wave forms of the ULF acceleration BCG and the second time-derivative of the flow (Fig. 4).

Derivatives of Arterial Pressure

After the administration of 0·25 - 1 mg. Inderal, small changes were noted in the recorded parameters. The blood pressure decreased and a decrease was also noted in the amplitudes of the ULF acceleration BCG and the first and second time-derivatives of the pressure. The systolic time

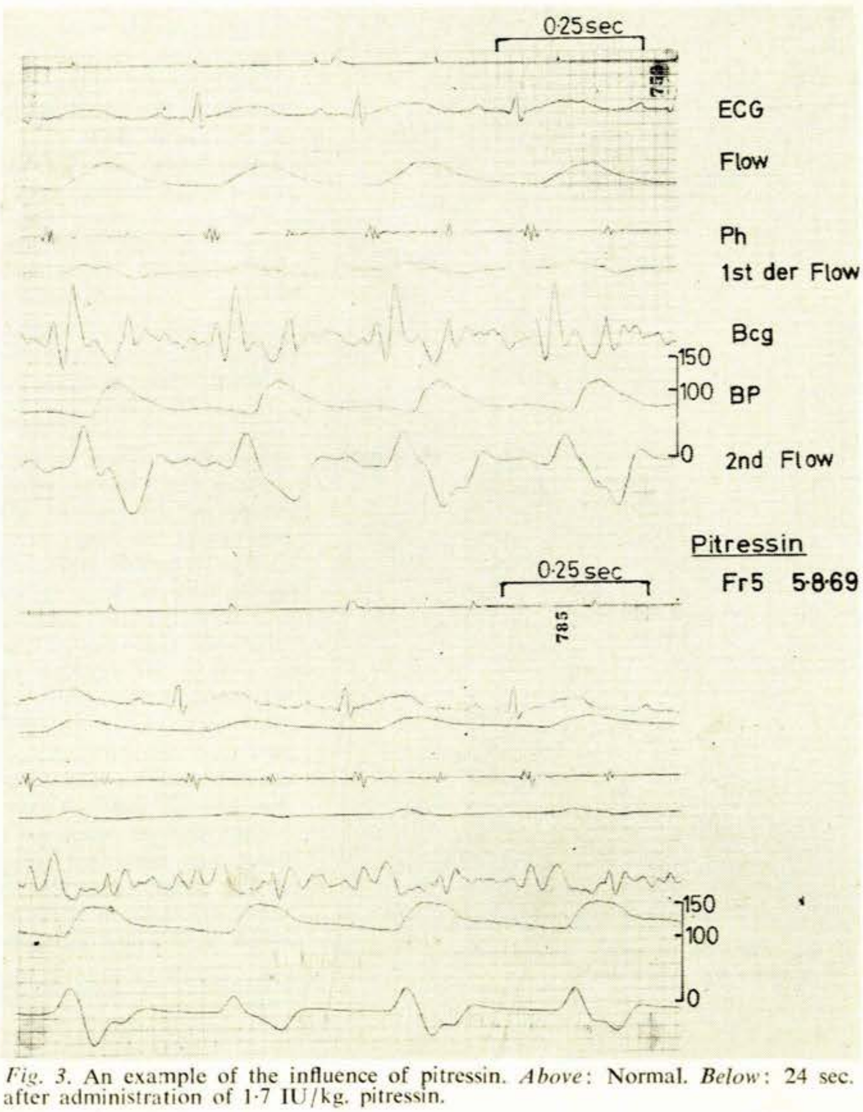

Fig. 3. An example of the influence of pitressin. *Above*: Normal. *Below*: 24 sec. after administration of 1·7 IU/kg. pitressin.

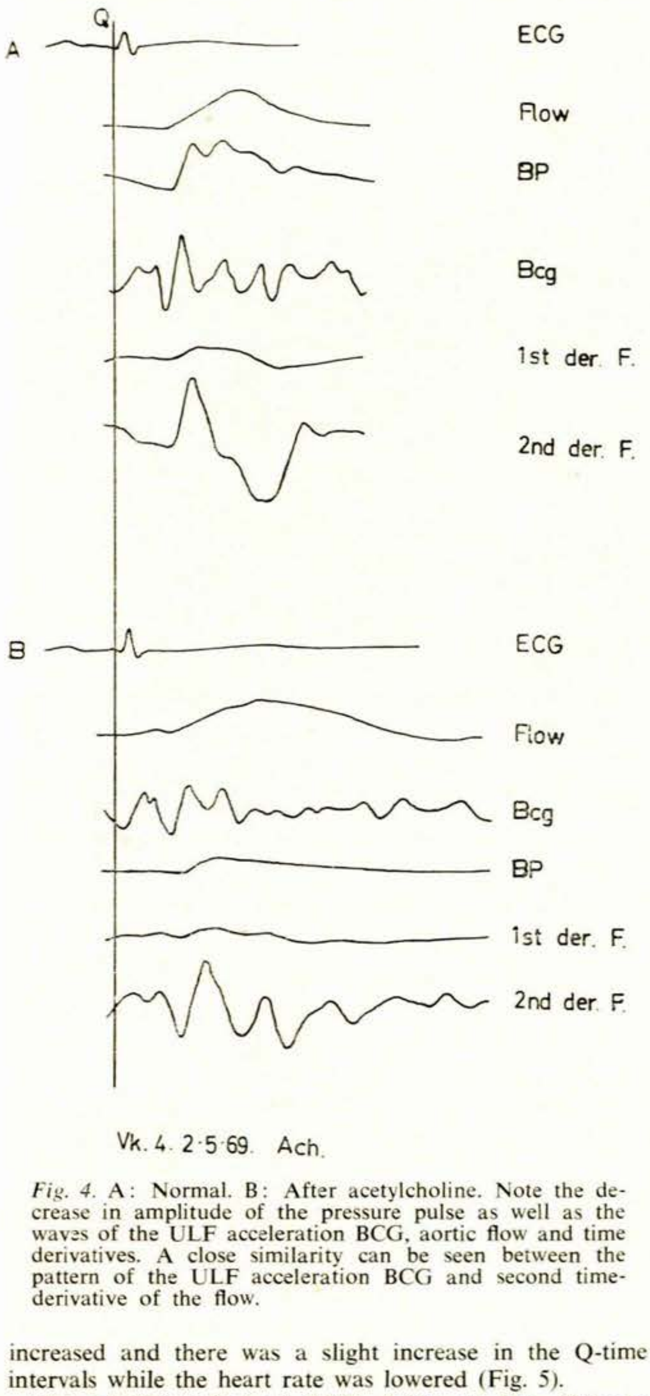

Fig. 4. A: Normal. B: After acetylcholine. Note the decrease in amplitude of the pressure pulse as well as the waves of the ULF acceleration BCG, aortic flow and time derivatives. A close similarity can be seen between the pattern of the ULF acceleration BCG and second time-derivative of the flow.

increased and there was a slight increase in the Q-time intervals while the heart rate was lowered (Fig. 5).

The administration of 0·027 - 0·615 mg./kg. Ildamen caused an increase in the amplitudes of the ULF acceleration BCG while the Q-time intervals decreased. Although the same changes were noted in the time derivatives of the pressure, they were not so conspicuous. The heart frequency remained constant. The different waves of the ULF acceleration BCG and the blood pressure showed the same changes in the pattern after the administration of 0·145 mg./kg. epoxyscillirosidin from *Homeria glauca* (Fig. 6).

DISCUSSION

A stimulating influence of amyl nitrite and adrenaline on the cardiovascular system is reflected in the changes in the ULF acceleration BCG and the time derivatives of the blood flow. Because acetylcholine has a depressant effect on the heart, both the contraction and the mass of ejected blood decreased. The different ULF acceleration BCG waves and the different waves of the time derivatives of the flow therefore decreased in amplitude.

Pitressin causes a lowered blood flow through the myocardium, and the efficiency of the heart is thus reduced. The conspicuous changes in the recorded parameters after the administration of pitressin illustrate clearly the depressant influence. The changes in the amplitudes and Q-time intervals of the ULF acceleration BCG and time derivatives of the flow are closely related to each other.

Inderal, a beta-adrenergic blocking agent, decreased blood pressure in dogs[6] and man.[7] Furthermore the QH-time interval increased and the heart rate decreased after Inderal administration.[7] The present experiments also illustrate a decrease in blood pressure and heart rate, while the QH-time interval increased. Other haemodynamic parameters such as the ULF acceleration BCG and time derivatives of the pressure also indicated a decrease in myocardial efficiency (Fig. 5).

Ildamen has a positive inotropic effect on the heart. It increases the amplitude of the pressure pulse while the heart frequency and ECG do not change.[8] Experiments done in this laboratory confirm that there is no change in heart frequency or ECG after the administration of Ildamen. Changes were only found in the ULF acceleration BCG and time derivatives of the pressure. These changes indicated that a more vigorous heart contraction was obtained after the administration of Ildamen.

From these results it is clear that there is a close relationship between the changes in amplitudes and the Q-time intervals of the IJ-segment of the BCG and the time derivatives of aortic blood flow and derivatives of the pressure.

Figs. 4 and 6 illustrate that, although there is a relationship between the pattern of the ULF acceleration BCG and the blood pressure pulse, a much closer relationship between the pattern of the ULF acceleration BCG and the second derivative of the aortic flow exists. The pattern of the time derivatives of the blood pressure did not show a close relationship to the ULF acceleration BCG, because much more high frequency signals were filtered out and also because the blood pressure gives more information about the lower dynamic functions of the cardiovascular system.

It seems as if the ULF acceleration BCG (especially the waves following the I-wave) gives more information about the higher dynamic events in the aorta. The systolic ULF acceleration BCG waves have a close relationship with the myocardial contraction. This is also illustrated during the abnormal beats in Fig. 6.

When the activation of the myocardium is abnormal, the co-ordination during myocardial contraction is not so good, as shown in the measured parameters. It is therefore concluded that the ULF acceleration BCG gives information about the co-ordination of myocardial contraction as well.

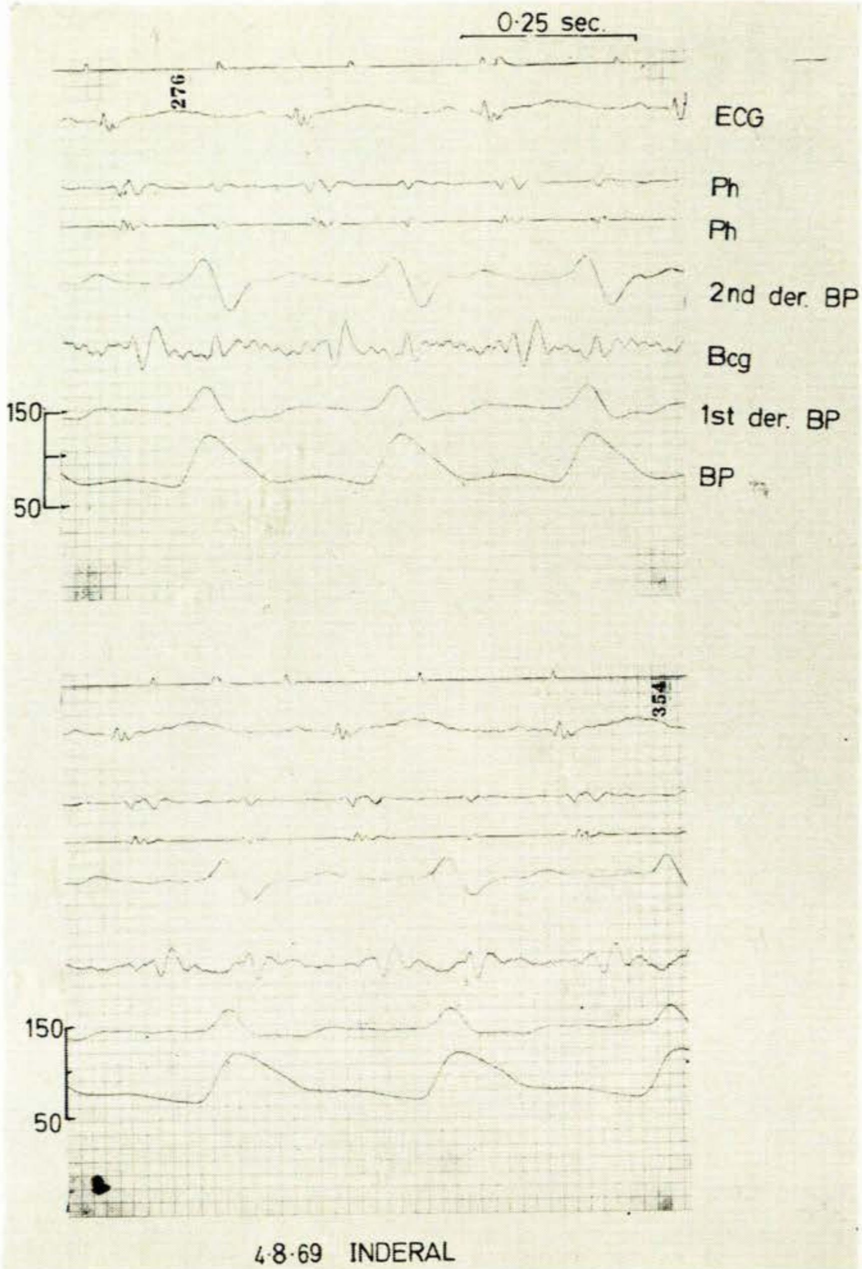

Fig. 5. An example of the influence of Inderal. *Above*: Normal. *Below*: 14 minutes after the administration of 0·1 mg. Inderal.

Because the first and second time-derivatives of the aortic blood flow showed the closest correlation with the ULF acceleration BCG, the conclusion was reached that most of the systolic ULF acceleration BCG waves (especially the IJ-complex) contain higher dynamic information related to the contractility of the myocardium.

SUMMARY

The ultra-low-frequency acceleration ballistocardiogram was compared with the first ($\frac{d}{dt}$) and second ($\frac{d^2}{dt^2}$) time derivatives of the aortic flow and blood pressure respectively where the aortic flow was recorded. The influence of pitressin, acetylcholine, adrenaline and amyl nitrite was analysed. The influence of Ildamen and Inderal on the ULF acceleration BCG, and time derivatives of the blood pressure were calculated. From these results it is concluded that a relationship exists between the ULF acceleration BCG and the time derivatives of the aortic flow and blood pressure. The ULF acceleration BCG gives information about the higher dynamic functions of the heart, like the co-ordination of heart contraction and the acceleration of blood flow in the aorta.

We wish to thank the CSIR and the Mealie Control Board who provided financial support for this research.

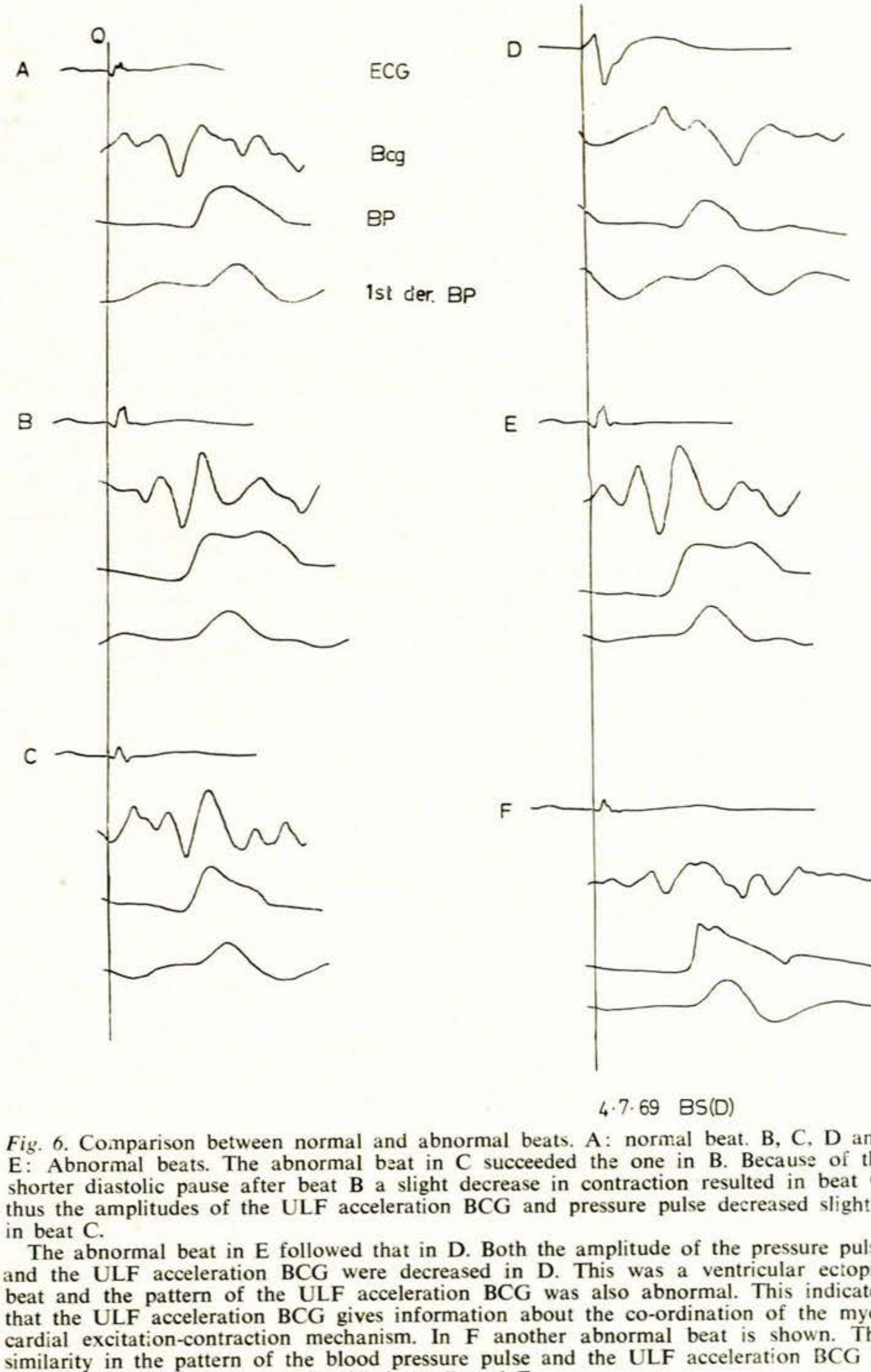

Fig. 6. Comparison between normal and abnormal beats. A: normal beat. B, C, D and E: Abnormal beats. The abnormal beat in C succeeded the one in B. Because of the shorter diastolic pause after beat B a slight decrease in contraction resulted in beat C, thus the amplitudes of the ULF acceleration BCG and pressure pulse decreased slightly in beat C.

The abnormal beat in E followed that in D. Both the amplitude of the pressure pulse and the ULF acceleration BCG were decreased in D. This was a ventricular ectopic beat and the pattern of the ULF acceleration BCG was also abnormal. This indicates that the ULF acceleration BCG gives information about the co-ordination of the myocardial excitation-contraction mechanism. In F another abnormal beat is shown. The similarity in the pattern of the blood pressure pulse and the ULF acceleration BCG is illustrated by comparing beat F with beats B and E.

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