

## SYMPOSIUM ON ASPECTS OF CARDIAC RESEARCH: SUMMARIES OF PAPERS

The following are abstracts of papers presented at the Symposium on Cardiac Research held in the Department of Physiology and Institute for Physiological Research, Potchefstroom University, on 21 August 1969:

### COMPARATIVE INVESTIGATIONS OF THE CARDIOVASCULAR FUNCTIONS OF DIFFERENT SPECIES

G. JUZNIC, *Institute of Physiology, Faculty of Medicine, Ljubljana, Yugoslavia*

The heart and the vascular bed represent a unity from the morphological and functional point of view. The heart has to overcome a resistance (R) made up of 3 components, caused by the inertia of the blood, distensibility of great vessels (elastic resistance—ER) and diameter changes of peripheral vessels (total peripheral resistance—TPR).

The rhythmic action of the pumping system gives us the possibility of recording the electrical, acoustical and mechanical phenomena, which are of interest especially during the adaptations to new conditions. The regulatory possibilities include chiefly the changes of 3 parameters of the cardiovascular system (CVS): blood pressure (BP), resistance (R, triple) and blood volume (BV).

A review of comparative investigations of the cardiovascular (CV) function made by the author on 5 species of mammals (mouse, rat, guinea-pig, rabbit and man) during the last 10 years, is given. Especially the ballistocardiographic (BCG) and Stewart-Hamilton dye dilution methods are used. The basic anatomical and physiological quantitative data of CVS were collected and correlations to body-weight calculated. Eight regression equations ( $y = a x^b$ ), representing the dependence of different CV parameters (y) from body-weight (x) were determined. The most characteristic conclusions are:

1. Some of the parameters of CVS are equal in all mammals: blood pressure, the sum of the durations of systole per minute, and the linear acceleration of the blood in the aorta.

2. The tension developed in the myocardium per minute and the  $O_2$  consumption of the heart muscle per minute have the same dependence from the body-weight in all mammals.

3. Based on conclusion 2, the hypothesis of haemodynamic stress and relief of the heart is developed: not only the TPR but also the ER can represent a load on the heart. The possibility of distinguishing the individual reactivity of man on different forms of stress is the practical consequence of this thesis.

4. The ballistic force represents a good indicator of the force of the heart (compared with the results of direct measurements).

5. BCG-acceleration records are useful in the studies of the influence of different agents on the heart, while BCG-displacement records reflect better the vasoactive influences on the CVS.

6. BCG-displacement, -velocity and -acceleration records can be a source of useful physiological information.

Some new techniques have been developed by the author recently, namely differential sphygmography (the difference between carotid and femoral pulse curve) and differential barography (the difference between the carotid and femoral blood pressure curve).

They represent new procedures, developed with the aim of eliminating some complexities of the BCG method and of enlarging the possibilities of studying the CV function in normal and abnormal conditions.

### EFFECT OF INDIGENOUS PLANT POISONS ON THE HEART

T. W. NAUDÉ, *Toxicology Section, Veterinary Research Institute, Onderstepoort, Tvl*

Of the 6 main plant poisoning syndromes of stock in Southern Africa, 3 have important effects on the heart. 'Gifblaar' poisoning is caused by *Dichapetalum cymosum*, the active principle being fluoroacetate. This is changed to fluorocitrate *in vivo* which then inhibits aconitase, thus blocking the tricarboxylic acid cycle. In ruminants, especially, the heart is affected primarily and poisoning leads to sudden cardiac failure.

'Gousiekte' is caused by 3 genera of the Rubiaceae, viz. *Pachystigma* spp., *Pavetta* spp. and *Fadogia* spp. A chronic fibrocytic myocarditis develops in this syndrome which affects ruminants only. Approximately 6 weeks after ingestion of the plant the animal dies of sudden cardiac failure. The phonocardiographic and electrocardiographic changes encountered during this latent period, were discussed. Research led to the conclusion that functional cardiac dilatation took place, cardiac ischaemia developed and that decreased cardiac

contractibility was encountered.

Cardiac glycoside poisoning due to bufadienolides in plants from the families Liliaceae, Iridaceae and Crassulaceae is responsible for serious stock losses. The ECG changes encountered in tulip poisoning in sheep due to *Homeria glauca* and its main toxic principle 1-alpha, 2-alpha-epoxyscillirosidin, were presented. Cardiac glycoside poisoning in sheep differs from that in man in several respects: Only minor ECG changes are encountered at dosage levels which do not cause serious poisoning. Furthermore, PR interval lengthening is only occasionally encountered and changes in the amplitude of the T wave occurs very infrequently. Bradycardia succeeded by sinus tachycardia and followed by AV dissociation and the establishment of nodal rhythm which eventually goes over into runs of paroxysmal tachycardia due to discharges from different ectopic foci, were the principal changes encountered.

### HIGHER DYNAMIC FUNCTIONS OF THE HEART IN CARDIAC RESEARCH

P. J. PRETORIUS, *Department of Physiology, Potchefstroom University, Potchefstroom*

The higher dynamic functions of the heart include measurement of myocardial functions related to the work and power of the heart. This can be accomplished experimentally by direct measurement of myocardial tension by means of implanted transducers as well as measurement of the rate of change of ventricular or arterial pressure or flow. The higher dynamic functions can be obtained from volume, pressure and flow recordings by means of electronic differentiation in order to derive the 1st and 2nd time-derivatives.

Indirect measurements, which may provide information comparable to that of the above-mentioned direct methods, should be based on the physical principles of the haemodynamic functions of the heart. Methods which may be of value in this respect include ultra-low-frequency ballistocardiography (BCG), electrokymography and apexcardiography.

Experiments on different animal species clearly indicated that the ultra-low-frequency acceleration ballistocardiogram contains a great deal of higher dynamic information. These

experiments included a wide range of mechanical, pharmacological and pathophysiological alterations of cardiovascular functioning. The conclusion was reached that the main systolic or IJ-complex is caused by blood flow acceleration in the arterial system and that it correlates well with direct recording of the blood flow from the aorta and with its time derivatives. A correlation was also found between the main systolic wave complex of the BCG and the arterial pressure pulse and its time derivatives. The genesis of the different pre-systolic and ejection waves could also be postulated from these results. Possible contamination in the HI-segment may be eliminated by new improvements of the method.

Different applications of the BCG and other haemodynamic methods showed their usefulness for experimental purposes. Experimental atherosclerosis and *gousiekte* (a toxic cardiomyopathy) were investigated by means of animal experiments. The influence of emotional stress situations as well as exercise was studied in humans.

### CARDIOVASCULAR RESEARCH IN HEAT STRESS

N. B. STRYDOM, *Chief, Applied Physiology Division, Human Sciences Laboratory, Chamber of Mines of South Africa, Johannesburg*

One of the most challenging facets of cardiac research is to be found in the field of applied physiology. Here we are dealing with the heart operating under various forms of stress while the condition of the vascular bed may fluctuate continuously between constriction and dilatation. In order to understand and explain such phenomena as physical conditioning and/or heat adaptation it is essential to study blood flow in subjects while they are being subjected to the stresses involved. The question then arises as to what would be the most reliable and suitable methods to use for assessing these changes. Obviously, those methods employed for determining cardiac output and blood flow at rest in cool conditions cannot always be directly transferred to the exercising and sweating individual.

Considerable research was done in order to develop suitable methods for determining the cardiac output during heat exposure. Another source of controversy is the standardization of variables such as type of heat and exercise, extent of dehydration, body composition of the subject, clothing, age, sex, state of health, extent of acclimatization, body position, etc.

Distinct differences in cardiovascular response were found between acclimatized and unacclimatized subjects by using the acetylene rebreathing and radio-isotope techniques. It was

proved that by the 3rd-5th day of acclimatization to heat, plasma volume, interstitial fluid volume and total body water increased, thus explaining the decrease in heart rate and increase in stroke volume observed by the third day.

It is obvious that only fully acclimatized individuals can be used in these experiments.

In studies done with well-trained, acclimatized subjects it was found that an increase in heart rate occurred at all levels of activity, while maximum values were reached at lower rates of energy expenditure during heat exposure. A decrease in stroke volume was found at all levels of exercise, with a possible exception at maximum effort. A possible explanation for this phenomenon is the fact that the main factor for an increase in cardiac output is the rate of metabolism of working muscle.

In acute exposure it was found that during intermediate levels of work in humid heat the large increase in skin blood flow was not adequately compensated for by vasomotor control. The result was that some blood was shunted away from the exercising muscles and these thus suffered from partial hypoxia as shown by the decrease in oxygen consumption for a set task and the formation of 'excess' lactate in the blood at lower work intensities than normally observed at room temperature.

### NEW APPROACHES TO FIBRILLATION AND DEFIBRILLATION IN CARDIAC SURGERY

G. G. JÁROS, *Section of Life Sciences, Atomic Energy Board, Pretoria*

The apparatus used to produce fibrillation necessary in open heart operations utilizes a 50 c.p.s. alternating current with voltage of between 30 and 40. In several hundred experiments on dogs and apes undergoing thoracotomy, we have shown that 2 volts is sufficient to obtain the smooth fibrillation desired by surgeons.

Rectangular pulses of 2-10 milliseconds duration at a frequency of 20-100 per second were produced. The stimulating electrodes (separated by a distance of 1 cm.) are pulled transversely (crossing the interventricular sulcus) along the epicardial surface. This method of inducing fibrillation makes it possible to employ a much smaller apparatus than those presently in use. The physiological basis is probably the creation of multiple foci of unequal excitability as a consequence of moving the electrodes during stimulation.

Defibrillators at present available do not convert fibrillation immediately and completely to normal rhythm. Different types of arrhythmia, such as certain electrocardiographic signs of myocardial lesions, which are more or less persistent, are often produced.

An elevated SGOT level associated with an abnormal ECG confirms the possibility of a real cardiac lesion. Although the importance of the electrocardiographic signs present after

defibrillation is uncertain, it is recommended to avoid them.

We have shown that the application of two shocks of identical shape and duration (condenser discharges), but of opposite polarity, administered at an interval of 400 msec., reduces these electrocardiographic signs.

The physiological justification for this method is based on the following:

1. The ionic imbalance caused by the first shock is corrected by the second.

2. The second shock depolarizes the fibres that were in fibrillation during the first shock, and were consequently refractory, and also depolarizes the fibres that were affected by the first shock given, the refractory period of the cardiac fibres being of 300-350-msec. duration.

The efficacy of these techniques has been controlled by alternative fibrillation and defibrillation in dogs. The apparatus was used in 2,000 instances without failure. A maximum of 180 shocks were given to a single animal. It has also been used on 15 patients.

The double shock has been used 100 times on a non-fibrillating heart without producing fibrillation, indicating its possible use in the termination of atrial or ventricular arrhythmias without the necessity of synchronization.

### THE DURATION OF THE CARDIAC ACTION POTENTIAL

J. J. VAN DER WALT, *Department of Physiology, Potchefstroom University, Potchefstroom*

The duration of the cardiac action potential is about 500 times that of the action potential recorded from a nerve fibre. According to the classical theory for the genesis and conduction of electrical activity the slow repolarization in cardiac fibres can be explained by assuming that the increase in potassium conductivity is very slow relative to the increase found for nerve fibres.

In order to determine the precise mechanism of repolarization in cardiac fibres, a technique of voltage-clamping was used. In a number of experiments using hyperpolarizing current to increase the membrane potential for periods lasting from 10 msec. to 10 sec. the following experimental results were obtained:

1. Hyperpolarization increases the duration of an action potential obtained after the termination of the hyperpolarizing pulse. This influence of hyperpolarization is a function of the duration as well as of the magnitude of hyperpolarization.

2. The influence of hyperpolarization on the duration of the action potential is more pronounced in a Tyrode solution

containing a high concentration of calcium ions.

3. The time course of the decrease in potassium conductivity shows no correspondence to the time course of increase in action potential duration, both as a function of duration of hyperpolarization. It therefore seems doubtful if the repolarizing phase of the action potential can be explained by only assuming an outflow of potassium ions.

4. By clamping the membrane potential at the plateau level immediately after termination of the spike of the action potential, experimental evidence was found for an inward calcium current flowing during the repolarizing phase of the action potential. The time course of change of this current shows a good correlation with the time course of increase in action potential duration, both as a function of duration hyperpolarization.

Our results are therefore in favour of a repolarizing phase of the cardiac action potential which can be explained by an increase in potassium conductivity as well as an increase in calcium conductivity.