Method of Obtaining Direct-Body Displacement-Velocity-Acceleration Ballistocardiograms of the Dog.* (21198)

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Animal experimentation was an essential phase in the development of electrocardiography and other cardiovascular methods, but as yet has contributed little to the study of ballistocardiography. Relatively limited animal experimentation has been conducted with the ballistocardiographic tables(1-3), and there have been no reports using the direct-body technic. This paper presents a modification of a human, direct-body technic(4), by means of which displacement, velocity and acceleration ballistocardiograms of dogs may be obtained. This technic permits the determination of ballistocardiographic alterations produced by drugs and by physiologic maneuvers under conditions not possible in the human.

Methods. Anesthesia was obtained either by a combination of morphine sulfate 2 mg/kg, subcutaneously, with urethane 1 g/kg, intraperitoneally, or by morphine sulfate 10 mg/kg, subcutaneously, with sodium pentobarbital 10 mg/kg, intravenously. Supplemental doses were administered when necessary. A concave aluminum rod was sutured to the spinous processes of 4 or 5 vertebrae between T-6 and L-5. The rod was made by transversely sectioning aluminum tubing of an inside diameter of 10/16 in. and an outside diameter of 12/16 in. The length of the rod was sufficient to extend at least 6 inches from the sacrum. The weights of the rods used in this study ranged from 40 g to 60 g, depending upon the size of the animal. The suturing of the rod to the spinous processes was easily accomplished by penetrating the skin, subcutaneous tissues and bone with a 15-gauge hypodermic needle and threading heavy cord through the needle. The animal was placed in the prone position in a wooden trough padded with 2-inch thick sponge rubber; the head was supported and the entire vertebral column was maintained in a straight line relation (Fig. 1). The front legs of the animal were placed under the head support, extended, but not restrained. The back legs hung loosely over the end of the dog board or were folded under the animal. Additional padding was added if necessary to keep the spine parallel to the floor. The animal was intubated and respired with oxygen by a rhythmic motor-driven interrupter connected to a constant pressure tank. The combination of morphine and urethane anesthesia produced excellent skeletal muscle relaxation and depressed the natural respiratory movements without depressing vagal tone. Lighter grades of anesthesia were produced with pentobarbital and morphine. The respirator was stopped during ballistocardiographic recordings leaving the lungs stationary in the expiratory position. The animal usually made no respiratory movements during the few seconds required for recording, but if such movements persisted, they were eliminated by a short period of hyperventilation.

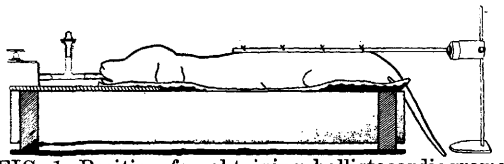

FIG. 1. Position for obtaining ballistocardiograms of anesthetised dog. Animal is shown intubated for positive-pressure administration of oxygen by a rhythmic interrupter. Aluminum rod sutured to dog's spine is maintained in continuous contact with sensing unit of the ballistocardiograph.

This method may be modified for the recordings of ballistocardiograms of the unanesthetized dog. Segments of nylon cord were inserted through each of several spinous processes, under pentobarbital anesthesia, and left indwelling. On subsequent days, the aluminum rod was tied to the spine without eliciting pain. Ballistocardiograms were obtained in this way as late as 2 weeks after the introduction of the nylon cord. The use of unanesthetized animals, while more physiological, in-

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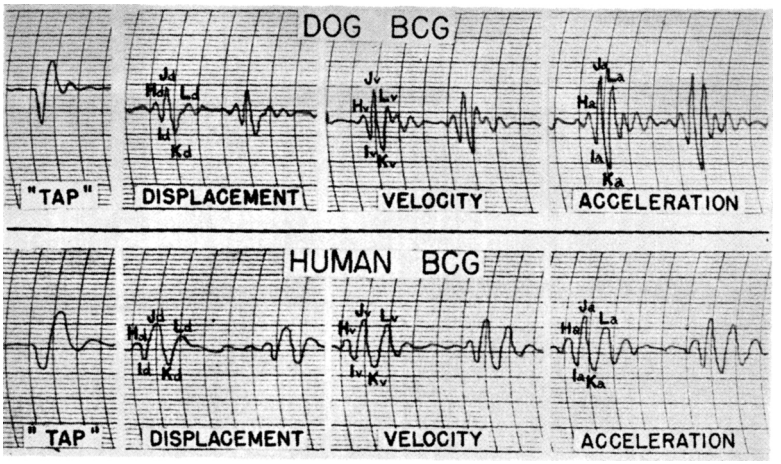

FIG. 2. *Upper tracings.* "Tap record," and displacement, velocity and acceleration ballistocardiograms of anesthetised dog. Recordings made 2 days after a strain gauge arch for measuring heart contractile force was sutured to right ventricle. *Lower tracings.* Ballistocardiograms of unanesthetised 27-year-old male with normal cardiovascular system. Dog and human tracings obtained during expiration. Vertical lines correspond to 0.2 sec. intervals.

troduces considerably more difficulty in the interpretations of recordings because of the artefacts of respiratory and voluntary movements. Accordingly, such recordings are satisfactory only with synchronous electrocardiographic recordings to aid in identification of ballistocardiographic complexes.

The Arbeit d-v-a ballistocardiograph(4)† was used to measure the displacement, velocity and acceleration of the animal's body movements. With each movement of the body, the rod sutured to the spine displaces the plunger of the sensing unit of the ballistocardiograph. The frequency response of the ballistocardiograph is better than 95% accurate from 2 to 20 cycles/second. The exclusion of higher frequency components is achieved through the use of an electronic low-pass amplifier. This is essential in order to eliminate artefacts due to ambient vibrations. Amplification, in the present experiments, was carried out by means of a direct-writing E.P.L. Cardiotron electrocardiograph. In several experiments, the output from this instrument was connected to a Brush B1-202 oscillograph. This oscillograph has recording speeds of 5, 25, and 125 mm/sec., and its 2 channels permit paired synchronous recordings of either ballistocardiograms, arterial pressures, electrocardiograms, or heart contractile force changes by a strain gauge method(6). The frequency response of the Cardiotron-Brush system was found to be flat over the entire experimental range by use of a Hewlett-Packard Low Frequency Function Generator (Model 202A). The natural frequency of the dog was determined by tapping the animal quickly on the head while the ballistocardiograph selector dial was set on "displacement" and the amplification of the electrocardiograph was greatly reduced to eliminate the recording of ballistocardiograms. Such a record is shown in Fig. 2. The natural frequency of the dog, in the position described above, was found to range from 4 to 8 cycles/sec. If the natural frequency of the animal was above 5 cycles/sec., it was lowered by increasing the thickness of the sponge rubber padding. The degree of damping as observed on the tap records ranged from about 0.3 of critical to nearly critical. The final natural frequency and degree of damping of the dog, positioned in this manner, approximates values found in the human. The light weight of the rod and its secure attachment to the spine insures faithful following of the body movements by the rod. In this respect, the dog ballistocardiogram has higher fidelity than that of the human, where the record is obtained from a shin-piece applied to the skin

† Manufactured by the Industrial Development Laboratories, Jersey City, N. J.

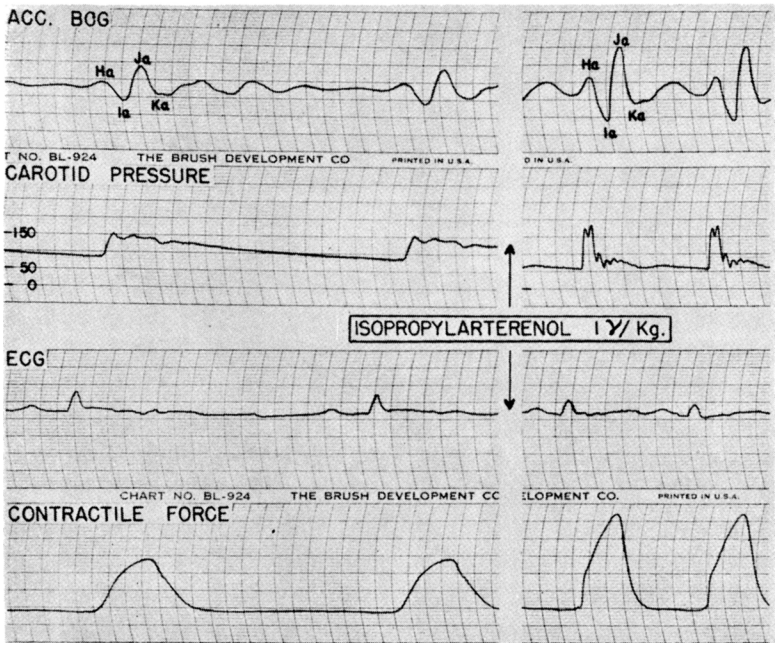

FIG. 3. High speed oscillographic recordings of acceleration ballistocardiogram, carotid blood pressure, electrocardiogram (LII), and heart contractile force of anesthetised dog before and after intravenous administration of isopropylarterenol. Scale on B.P. tracing indicates mm Hg. Heart contractile force proportional to excursion amplitude. Tracings obtained 2 days after a strain gauge arch was sutured to right ventricle. Vertical lines correspond to .04 sec. intervals.

with its underlying layers of elastic media. The choice of displacement, velocity or acceleration recordings in dog ballistocardiography involves essentially the same factors as in the human(4,5). The mathematical process of differentiation from displacement to velocity to acceleration results in an emphasis of high frequency components and a minimizing of low frequency waves. If the amplitude of response of a linear physical system to an input of sinusoidal force of constant amplitude is plotted with respect to the ratio, Forcing Frequency/Natural Frequency, it is found that only those frequency components below the natural frequency of the body are accurately measured by displacement curves, whereas higher frequency components can only be obtained by acceleration recordings. Since the natural frequency of the dog was lowered to approximate values found in the human, and since almost all of the disturbing forces seen were of a higher frequency than the natural frequency, acceleration recordings were almost exclusively used in the present study. Without anesthesia, only acceleration recordings could be obtained because displacement and velocity tracings were distorted by the low frequency respiratory and skeletal muscle movements.

Results. Preliminary experiments(7) with the Dock electromagnetic ballistocardiograph (8) yielded tracings which were an indeterminable mixture of displacement and velocity and the use of this instrument was discontinued.

The tap record, and displacement, velocity and acceleration ballistocardiograms of an anesthetized dog are illustrated in Fig. 2. The wave components and contours are similar to those obtained with the human as may be noted on comparing those tracings with the recordings in the lower part of the illustration.

Fig. 3 illustrates the effects of 1 γ/kg of isopropylarterenol, intravenously, on the synchronously recorded acceleration ballistocardiogram, electrocardiogram, heart contractile force(6) and carotid pressure of an anesthetized dog. The ballistocardiographic effects produced by isopropylarterenol in the dog are similar to those observed in the human by

Kaufman, Iglauer, and Herwitz(9). As may be noted in Fig. 3, the Ia-Ja amplitude of the acceleration ballistocardiogram increased by an increment of 100% of control values; heart contractile force increased by approximately the same increment. The Ia-Ja time was reduced from .04 to .02 sec.; the total time of the heart contractile force curve decreased from .23 sec. to .14 sec. There was a 30 mm decrease in diastolic pressure and a 40 mm increase in systolic pressure. The heart rate increased from about 85 beats/min. to 220 beats/min. The increased Ia-Ja amplitude and contractile force along with shortening of the Ia-Ja time and the curve of contractile force change are consistent occurrences with this drug. The relation of these changes and those of arterial pressures and heart rate is being studied. A preliminary report(10) has been published describing changes produced by other sympathomimetic amines in the dog and human acceleration ballistocardiogram.

Summary. A method of obtaining direct-body displacement, velocity and acceleration ballistocardiograms of the dog has been described. Ballistocardiograms obtained by this method are similar to those of the human.

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Stability of Vesicular Stomatitis Virus at Varying Hydrogen Ion Concentrations. (21199)

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Various workers(1-5) have studied the stability of vesicular stomatitis virus at varying hydrogen ion concentrations. The detailed investigations of Galloway and Elford(5) have demonstrated the loss of viral infectivity at approximately pH 4.0 and its persistence at pH 9.6. Their criterion for survival of infective virus consisted of presence of characteristic lesions in the foot pads of guinea pigs inoculated intradermally with virus. No information is given on the stability of virus beyond pH 9.6 and no quantitative data are available concerning the actual number of infective viral particles surviving at any given hydrogen ion concentration. The lack of adequate quantitative data as well as the possible consequences associated with the common practice of disinfection of infected materials with sodium hydroxide emphasized the need for reexamination of this problem. The present studies utilizing more sensitive experimental hosts (mice and embryonated eggs as opposed to guinea pigs) in viral infectivity tests, report quantitative data on the survival of 2 strains of vesicular stomatitis virus over a wide range of pH.

Materials and methods. The viruses used in these studies were the New Jersey and the Indiana strains of vesicular stomatitis. These strains had histories of passages in various experimental hosts; the most recent passages were made in embryonated eggs via the al-