Blood Pressure Responses of Wild Giraffes Studied by Radio Telemetry

Abstract. *Blood pressure was telemetered from transducers chronically implanted in the carotid arteries of two adult, wild, male giraffes captured and released near Kiboko, Kenya. Cerebral perfusion pressure ranged from 280/180 mm-Hg while the animal was lying with its head on the ground to 125/75 mm-Hg when it was standing erect; it varied between these levels during spontaneous activity such as walking, grazing, and running.*

The cerebral circulation in giraffes presents some interesting hemodynamic problems. Significant hypertension must be generated to propel blood to the giraffe brain 2 m or more above heart level at pressures adequate to insure cerebral perfusion. Special compensatory methods of regulation have been postulated as necessary to protect the cerebral vessels from the great increase in pressure which must occur when the head is lowered, to drink, for example. Although the organs located below heart level may be chronically exposed to this unusually high pressure, no special mechanisms for buffering the microcirculation in these areas have been described. A basic step in understanding the regulation of giraffe circulation is determining the normal range of blood pressure in this animal.

Measuring blood pressure in the giraffe has been tried at least twice previously (*1*, *2*). In the better-documented study, hemodynamic measurements, including blood pressure, were made in four captive 12-foot (3¾-m) giraffes. One animal died of hypotension during the tedious 4-hour procedure. Authors of these works have subsequently questioned whether values obtained were normal for this animal, and have suggested that telemetry of blood pressure from an animal freely moving in his natural habitat would be necessary to determine normal values (*3*). A recent field trip to East Africa to study the cardiovascular system of feral baboons (*4*) gave us an opportunity to record blood pressures from two freely ranging giraffes via radio telemetry.

Two 14-foot (4¼-m) adult male giraffes were captured from separate herds on the plains around Kiboko, Kenya, East Africa, on successive days by a professional trapper and his crew. The highly skilled crew separated the desired giraffe from the herd, lassoed it from a platform on a fast, maneuverable vehicle, and hobbled it flat on the ground within 90 seconds (*5*).

As soon as the animal was secured, the midline of the neck, about 40 cm below the angle of the jaw, was infiltrated with 2-percent procaine, and a 15-cm vertical incision exposing the trachea and carotid arteries was made. A 10-cm section of the right carotid artery was isolated between vascular clamps, a 1-cm longitudinal slit was made in the section, and a small blood-pressure transducer was inserted into the lumen. Edges of the arteriotomy were closed around the shank of the transducer and approximated with interrupted 5/0 silk ligatures. The vascular clamps were removed, circulation was reestablished, and the wound was closed in layers. Wires from the transducer were brought to the outside between skin sutures and attached to a telemetry pack secured to the animal's neck with adhesive tape (Fig. 1). Surgery required less than 20 minutes; the artery was occluded for less than 10 minutes, but the animals were kept on the ground for 31 and 36 minutes, respectively.

The blood-pressure transducer was a small, chronically implantable gage consisting basically of a stainless steel wafer, 9 mm in diameter and 3 mm thick (*6*). In brief, the anterior end is a diaphragm with four silicon semiconductor strain gage elements mounted on its inner surface in the electrical configuration of a Wheatstone bridge. The posterior end holds a shank, 10 mm long and 3 mm in diameter, which contains the wires leading from the bridge. When implanted intraluminally, the diaphragm is in direct contact with the blood, while the shank exits through the arteriotomy wound. Changes in pressure within the vessel are sensed by the diaphragm and are transduced to changes in the bridge's output voltage. Dynamic frequency analysis of the system has been carried out with a fluid-filled piston phone; the output is flat to 24 cy/sec.

For telemetering blood pressure the bridge was excited by an external 5.1-volt mercury cell. The gage output was amplified by a low-gain transistor amplifier and fed into a channel 13 voltage-controlled oscillator. Thus changes in blood pressure were transduced to changes in frequency; this signal then modulated a 100-Mc/sec, frequency-modulated carrier so that an FM/FM signal was radiated. To recover the pressure information the signal was received and demodulated with an FM receiver. The changes in frequency proportional to blood pressure were converted to an analog voltage via a channel 13 discriminator (*7*).

Data received in the field was recorded directly onto magnetic tape with a Lockheed portable four-channel tape recorder. The entire system was calibrated from 0 to 300 mm-Hg immediately before installation and immediately after removal from the animals.

Recording was started while the animals were lying flat on the ground and was continued as restraints were removed and the animals regained their feet and galloped off. The first giraffe moved into rocky territory impassable to vehicles and was temporarily lost; it was found several hours later 13 miles away, feeding with its herd. The second animal stayed on the plains and was only temporarily lost from view. Both animals were subsequently recaptured, in each case after a vigorous chase in which they were thoroughly exercised. The incisions were then reopened, carotid arteries reexposed, transducers removed, arteriotomies repaired, and the animals released to rejoin their herds. Both were marked for ease of identification in case of subsequent death; however, such was not reported to area game scouts or trappers who were alerted to this possibility.

The heart rate of both giraffes lying flat on the ground was 90 beats per minute. The phasic wave form of carotid artery blood pressure in this posture was marked by an initial spike with a rapid ascent (2500 mm-Hg/sec) to about 280 mm-Hg. Carotid pressure at the end of diastole was about 150 mm-Hg. Systole lasted about 300 msec and diastole about 380 msec. Cyclic fluctuations of about 15 mm-Hg in systolic blood pressure occurred with respiration.

When restraints were removed, both giraffes raised their heads upright but remained a few seconds with legs folded under their bodies before struggling to their feet (Fig. 1). As they raised their heads to about 2 m above heart level, heart rate transiently dropped from 90 to less than 60 beats per minute (Fig. 1). Immediately after they stood up, the blood pressure was 190/120 mm-Hg and heart rate was 150 beats per minute (Fig. 1).

Both animals were observed walking about the plains, nibbling leaves from the trees, and occasionally standing still. During walking the carotid blood pressure ranged between 140/90 and 180/120 mm-Hg (Fig. 1). When standing quietly, apparently unconcerned and surrounded by other giraffes, carotid blood pressure was 150/105 to 170/110 mm-Hg. Effective cerebral perfusion pressure, determined by correcting for the vertical position of the gage, thus ranged from 280/160 when the animal was prone to as low as 110/60 mm-Hg when it was upright.

Recapturing the giraffes required several minutes of hard running, as the animals maneuvered to avoid the capture rope. During the chase, heart rate reached 170 beats per minute and peak blood pressure was 230/125 mm-Hg. Each time the animals' front feet hit the ground, blood pressure dropped sharply, presumably due to acceleration of blood in the carotids as the animal jolted up and down (Fig. 1). Later, after the animal had lain on the ground for 10 minutes, with its head at heart level, carotid blood pressure was again 280/160 mm-Hg and heart rate was 100 beats per minute.

In general, pressures recorded in this study were slightly lower than those reported by Goetz *et al.* (*2*). This may reflect differences in technique, since their animals had been in captivity for 9 months, were hobbled in the upright position during the study, and received drugs and anesthetics during the 4-hour period of measurement, and at least one

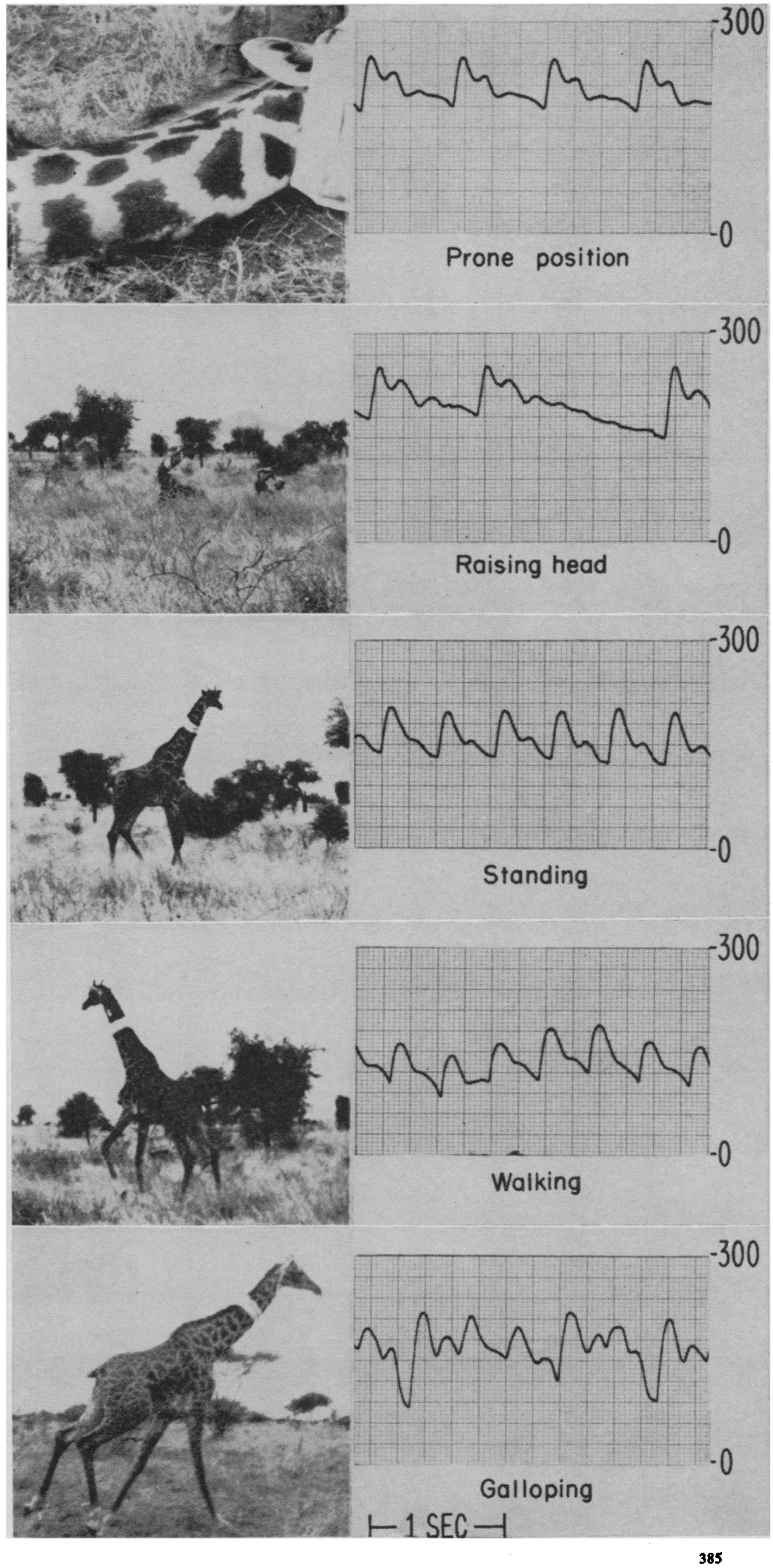

Fig. 1 (right). Phasic wave forms of giraffe carotid artery blood pressure during spontaneous activity. Level at which pressure was sampled is indicated by operative site shown in top photograph; blood pressure when lying prone was 280/180 mm-Hg. When the giraffe raised its head a transient bradycardia occurred. After the animal had been released to rejoin its herd and was slowly walking about, the blood pressure was as low as 150/90 mm-Hg. Recapture required a vigorous chase, during which the blood pressure reached 220/150 mm-Hg and the heart rate 170 beats per minute. Cyclic drop in blood pressure during galloping was synchronous with the animal's front-hoof beats.

died of hypotension during the procedure. The phasic wave forms of carotid artery blood pressure recorded in this study were similar but not identical to those recorded by Goetz, *et al.* with a catheter tip manometer (*2*). They also recorded an initial spike which was less marked in the central aorta, but became more prominent as the sampling catheter was moved peripherally. However, their most peripheral sampling point was barely above heart level, whereas in the present experiments the transducer was located at least 180 cm above heart level. Although wave forms which we recorded were probably greatly damped during transmission through this great length of the artery, no definite statement can be made about the role of reflected waves.

When the animal's neck and head were upright, blood pressure at the base of the skull was approximately 45 cm-H_2O (or 35 mm-Hg) less than that measured by the gage, owing to the effect of the hydrostatic column of blood above the gage. However, when the animal's head was on the ground, intravascular pressure at the gage site was essentially the same as at the base of the brain. Thus, while the animal was upright, the actual perfusion pressure at the base of the skull averaged about 125/75 mm-Hg, which compares favorably with known values for many other species, including man.

Excellent collateral circulation between major vessels supplying the giraffe's rete mirabile was observed directly. Functionally, this was demonstrated by lack of evidence of neurological deficit in both animals, despite the 10-minute continuous occlusion of the right carotid artery during gage installation. Further, blood pressure above a carotid occlusion was identical to that below it.

Both the present study and that of Goetz have shown that the change in cerebral perfusion pressure which occurs with postural variation does not correspond exactly to the measured change in effective height of the fluid columns between heart and head. This suggests that a means for blood pressure regulation may exist in which posture is involved. Additional evidence for such a mechanism is the transient bradycardia observed during head raising. Interrelationships between blood pressure and heart rate are characteristic of carotid sinus baroreceptor mechanisms. Although previous anatomical studies have indicated that the carotid sinus is absent in the giraffe (*2*) it seems likely that its function in regulating the cardiovascular system is served by other similar but as yet undetermined compensatory mechanisms.

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5. The giraffes were trapped and later recaptured by Barry White, chief professional wild animal trapper for John Seago Ltd., Nairobi, Kenya. We owe much of our success to White's patience and to the skill of White and his crew.
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8. We are indebted to A. H. J. Jenkins, chief warden, Kenya Department of Game, for permission to conduct this study. Supported by grants HE 08433 and HE 09217 from the USPHS and a grant from the Washington State Heart Association.

14 January 1966

Lake Lundy Time

Within the Erie Basin, between the highest level of Lake Maumee (800 feet) and that of Lake Erie (573 feet) the ice-dammed Lake Lundy has been assigned an elevation of 620 feet (190 m). Wood from a forest bed above the highest and most recent clay deposited by the falling lake waters, reported to Libby as taken at the 620-foot contour, was dated by him (sample C-526) at 8513 ± 500 years ago (*1*). This has led to acceptance of that figure as the date for Lake Lundy.

Hough (*2*) has since rejected this date, along with that of Lake Warren at 9640 years ago, as too recent, citing evidence that the Niagara outlet was cleared of ice necessary to maintain these lake levels before the Two Creeks interval (11,800 years ago). Falconer, Andrews, and Ives have also shown that the southern ice border 8000 to 9000 years ago lay far north of the Niagara outlet (*3*).

Actually the wood collected lay at least 6 feet below the surface at point of collection (*4*); it was covered with marl deposited by calcareous springs after recession of the lake. Hence the forest bed was not higher than 614 feet, where forest could not have grown until after the water fell below the assigned level (620 feet) of Lake Lundy.

However, the collection site described by R. J. Bernhagen, when located on the 1959 7½-minute Bellevue, Ohio, quadrangle (contour interval 5 feet), appears to lie below the 615-foot contour, rather than at the 620-foot contour, where it lay on the older (1901) 15-minute quadrangle (contour interval 10 feet). If this is the case the forest bed lies not higher than 609 feet. Since the forest bed and the marl above it are terrestrial deposits, the 609-foot elevation of the dated wood indicates a still greater interval between the presence of Lake Lundy at this point and the development of the forest bed.

Meanwhile Forsyth (*5*) includes Grassmere at 640 feet, Dana at 620 feet, and Elkton at 615 feet as three "Lundy" phases following erosion of the outlet of Lundy proper. This interpretation, rejecting the conventional 620-foot elevation used in the literature, also supports the view that the date of 8513 ± 500 years ago is much too recent for the last ice-front lake in the Erie basin.

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6. Thanks are due the Ohio Geological Survey and the National Science Foundation, and to Professors Forsyth, Ogden, and Crowl for accompanying me on a recent trip to the site.

7 March 1966