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High Threshold Aortic Baroreceptors Afferents in the Sympathetic Nerve of Monkey

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Abstract A total of 25 afferent units were recorded in the thoracic sympathetic rami (T_3–T_4) localised at the base of the bracheocephalic trunk and the descending aorta. Two types of receptors, Type I and Type II, were found. Type I receptors, localised at the base of the bracheocaphalic trunk, were fast adapting and exhibited synchronous discharge with each systolic height of blood pressure and behaved like baroreceptors. There was no discharge at the diastolic phase of the cardiac cycle. These receptors also gave occasional single spike at each systolic height of pressure of about 90–120 mmHg. When the systemic pressure was increased from 120 to 180 mmHg due to occlusion of the descending aorta or intravenous administration of adrenaline, the frequency of discharge of Type I receptors increased and they behaved like the typical sino-aortic baroreceptors. Type II receptors, localised over the wall of the descending aorta, fired irregularly and they did not have any relation with heart beat and did not behave like baroreceptors. On the basis of the present observation it may be suggested that Type I receptors are high threshold baroreceptors which play a role in the homeostatic control during high blood pressure and that Type II receptors do not play such a role.

Key words: Sympathetic afferents, descending aorta occlusion, Type I receptors, Type II receptors, high threshold baroreceptors.

KOLEY *et al.* (1985) have reported the presence of two distinct types of receptors (Type I and Type II) in the aorta of cat recorded in the sympathetic rami at the level of T_3 and T_4. Further, they have suggested that Type I receptors are high threshold baroreceptors and that like other systemic baroreceptors they play a role in homeostatic control presumably in a state of high blood pressure and that Type II receptors do not play such a role. However, little is known about the aortic receptors with sympathetic afferents and their reflexes in monkeys.

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In the present study an attempt has been made to investigate the sympathetic afferent nerve innervation of the aorta in monkeys. Further attempt was also made to investigate in detail the properties of the afferent sympathetic fibres with aortic receptors which are likely to be involved in homeostatic control of blood pressure in a state of high blood pressure.

METHODS

Investigations were carried out on 15 adult monkeys (3–4 kg body weight) of either sex anaesthetised with sodium pentobarbitone (Nembutal, Abbott Laboratories, India) using an initial intraperitoneal dose of 35–40 mg/kg body weight and maintaining anaesthesia with intravenous doses of 10 mg/kg as and when required. The trachea, femoral vein, and femoral artery were routinely cannulated. Blood pressure was recorded through a pressure transducer (Type 4-327-0129, Bell & Howell, CBC Division, U.S.A.) from the femoral artery. The chest was opened by removing the upper seven ribs on the left side of the chest, and the animal was kept under artificial respiration with Starling Ideal Respiratory Pump (INCO, Ambala, India). Glucose (5%) in saline was administered by drip into the femoral vein to maintain the normal body fluid. The body temperature was also monitored by recording rectal temperature which was maintained at 37–38°C by a heating blanket.

The membranous covering of the inner body wall around the region of the stellate ganglion and 1st to 5th sympathetic rami was separated out carefully and extended medially without causing any rupture so that the liquid paraffin pool for nerve dissection could be prepared. The left stellate ganglion and its branches were exposed carefully. Suitable lengths of the thoracic sympathetic rami were separated from the surrounding connective tissue under a stereoscopic dissecting microscope (Vickers Instruments, England).

The nerve was placed on a black ebonite dissecting plate and kept immersed in a warm paraffin pool. A small length of afferent thoracic rami at the level T_2 to T_4 was desheathed and split into fine filaments under a stereoscopic dissecting microscope. A fine filament of the peripheral cut end was placed on a pair of silver-silver chloride recording electrodes for studying single unit activity. The single unit activity was displayed on a dual-beam oscilloscope (5112, Tektronix Inc., Beaverton, U.S.A.) after amplification through a differential preamplifier (AM 502, Tektronix Inc.). Parallel connection was made to an audioamplifier for monitoring the sound and to a therminonic 4 FM tape recorder (Racal-Thermionic Ltd., Southampton, England) for recording the activity when necessary and played back to a storage oscilloscope (5113, Tektronix Inc.) for further analysis and photography. After obtaining the single unit activity, localisation of the receptor site was made precisely with a fine round tipped glass probe in the beating heart. The conduction velocity of these fibres was measured by peripheral stimulation technique (IGGO, 1958). The receptor site was stimulated by a square wave monophasic

pulse (7 to 10 V, 1 ms, 0.2–1 Hz) delivered from a stimulator (Grass S48, Grass Instrument Co., Quincy, U.S.A.) via an isolation unit (SIU5). To study the reactivities of the aortic receptors in hypertensive condition, the descending aorta was occluded. Occlusion of the descending aorta was done by putting a fine snare around the aorta and occluding it whenever necessary. Care was taken to see that the snare was very light and did not cause any mechanical irritation. Hypertensive agents like adrenaline were injected intravenously.

The aortic receptors were differentiated into Type I and Type II receptors according to the criteria followed by KOLEY *et al.* (1985). To confirm the observation, statistical analysis with the Student's *t*-test was performed for synchronous or asynchronous discharges with the systolic height of pressure.

Drugs used. PGE_2 and $PGF_{2\alpha}$ (Upjohn Co., U.S.A.), Angiotensin II, succinylcholine (Sigma), P.D.G. (Aldrich Co.), adrenaline (Burroughs Welcome, India).

RESULTS

a) Aortic receptors of monkey

In total, 25 single unit activities were recorded from the thoracic sympathetic rami T_3 and T_4 of the monkeys. Out of these 25 units, 17 units were synchronous with heart beat and responded with the systolic height of blood pressure. The remaining 8 units were irregular and asynchronous with both heart beat and systolic height of pressure. The receptors that synchronise with heart beat and fire at systolic height of pressure have been designated as Type I and those which are asynchronous have been designated as Type II receptors by KOLEY *et al.* (1985). Accordingly, the 17 units (those which were synchronous) and the 8 units (those which were asynchronous with heart beat) were grouped as Type I and Type II receptors, respectively. Out of the 17 units, 11 units were nonspontaneous and the

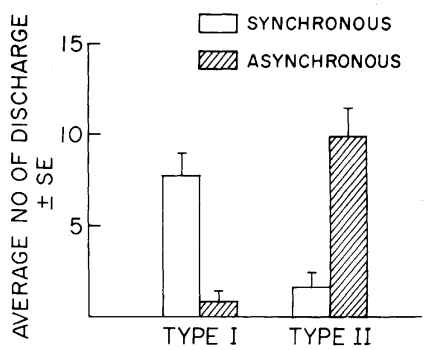


Fig. 1. The average number of discharges (±S.E.) synchronous and asynchronous with the systolic height of pressure during 10 cardiac cycles for Type I ($p<0.001$) and Type II ($p<0.001$) receptors, respectively.

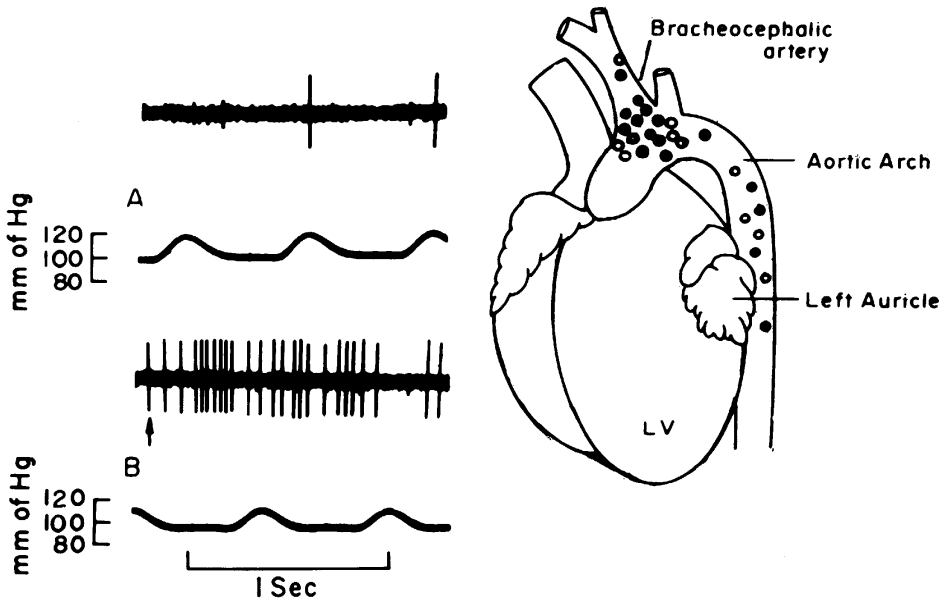


Fig. 2. The right panel is a schematic diagram showing the distribution of sympathetic aortic recptors of monkey over the aortic arch around the base of the bracheocephalic artery and descending aorta. Open circles indicate spontaneous and closed circles indicate nonspontaneous receptor sites. The receptors localised at the base of the bracheocephalic artery are of Type I and those over the descending aorta are Type II receptors. The left panel shows the spontaneous (A) discharge pattern of one typical Type I aortic receptor in monkey and its reactivity to mechanical probing (B). L. V., left ventricle.

rest were spontaneous (Fig. 2). Among the 8 units, 4 units were spontaneous and the rest were nonspontaneous (Fig. 2). Differentiation of Type I and Type II receptors was confirmed by performing the Student's t-test with the number of synchronous and asynchronous discharges to the height of systolic pressure during 10 cardiac cycles. It was observed that the number of synchronous and asynchronous discharges for Type I and Type II receptors, respectively, were significantly ($p<0.001$) high (Fig. 1).

Type I receptors in monkeys were located at the base of the bracheocephalic trunk and behaved like other systemic baroreceptors (HEYMANS and NEIL, 1958) with the exception that these receptors were of high thereshold type. At the resting systolic pressure head below 90 mmHg, these Type I receptors failed to give any discharge but when the systolic pressure went beyond 90 mmHg, then unit activity started to appear. The average resting discharge rate of these units at a pressure head of 90–120 mmHg was 1–3 impulses/s. On mechanical probing, this discharge rate increased to 12–20 inpulses/s (Fig. 2). Frequency of discharge was increased with the rise of systolic pressure following occlusion of the descending aorta (Fig. 3) or

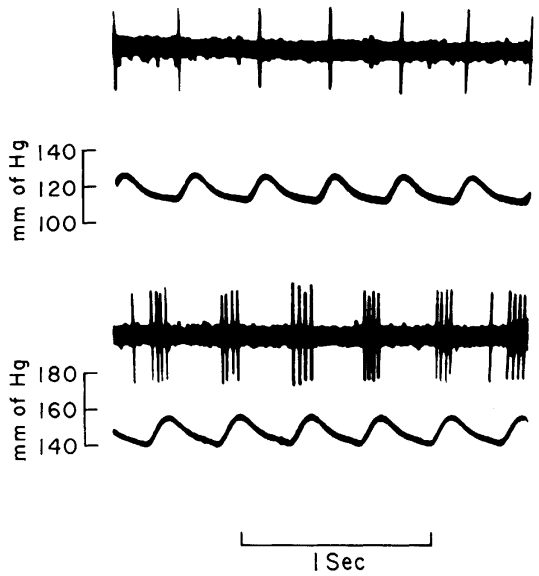


Fig. 3. The discharge pattern of one Type I aortic receptor to occlusion of the descending aorta in monkey. Upper panel shows the normal resting discharge pattern of one single unit and lower panel shows the increased frequency of discharge of the same single unit during occlusion. Within the panel, upper tracing shows the single unit discharge and lower tracing shows the arterial blood pressure.

intravenous administration of adrenaline at a dose of 10–15 μg/kg (Fig. 4). Threshold blood pressure for stimulating these Type I receptors range from 90 to 120 mmHg. The number of observations against threshold blood pressure is presented in Fig. 5. It is apparent from Fig. 5 that the majority (12 out of 17) of the receptors had threshold pressure in between 96–114 mmHg. The threshold pressure for activating the receptors was determined by noting the pressure at which the unit just started to discharge and disappeared with a slight drop of this pressure level. From the graphical representation (Fig. 6), it is apparent that single spike discharge rate of aortic receptors increased gradually with increase of blood pressure. After the administration of adrenaline (10–15 μg/kg) intravenously, systolic pressure increased from 120 to 180 mmHg and discharge rate increased from 1.2 ± 0.2 to 4.2 ± 0.19 impulses/beat (Fig. 6). These receptors showed the typical rapidly adapting dynamic behaviour of the baroreceptors. There was no discharge at diastolic phase of the cardiac cycle even when the diastolic pressure was much higher than the threshold pressure. The conduction velocity of these sympathetic afferents was found to be in the range of 3.15 to 9.84 m/s. The present study indicates that the impulse traffic from aortic baroreceptors is also carried through the thoracic sympathetic afferents (T_3 and T_4). These Type I receptors are effective only at high pressure level and may be described as high threshold baroreceptors.

Type II receptors, described earlier, are distributed over the wall of the

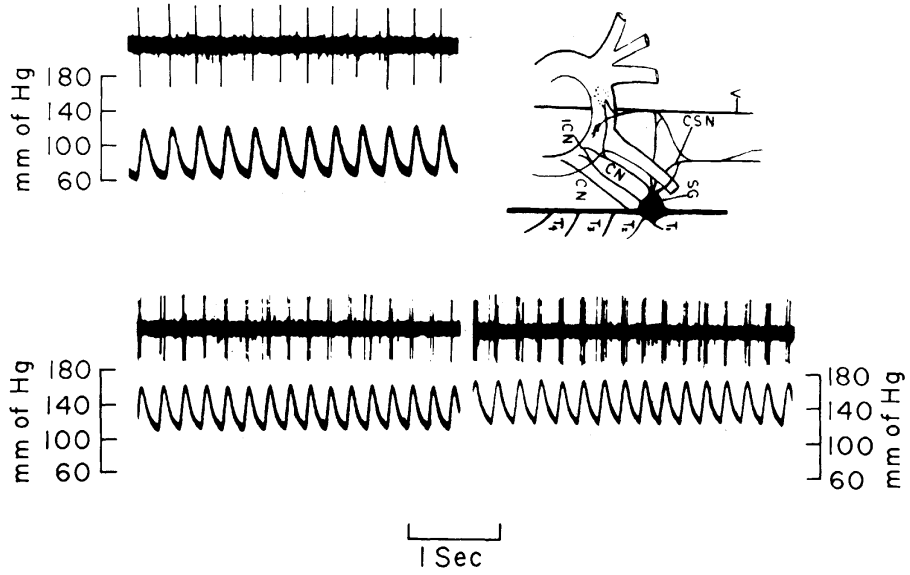


Fig. 4. Typical sympathetic baroreceptor discharge pattern to gradual rise of systemic pressure induced by infusing adrenaline (10 μg/kg i.v.). Upper panel (left side) shows the normal resting discharge of one single unit with pressure peak and lower panels (left and right side) show the increased frequency of discharge during the rise of pressure after adrenaline infusion. Within the panels, upper tracing shows the single unit discharge and lower tracing shows the arterial pressure. Right upper insertion shows the aortic arch along with the nerves. V, vagus; CSN, cardiac sympathetic nerve; SG, stellate ganglion; CN, cardiac nerve; ICN, inferior cardiac nerve.

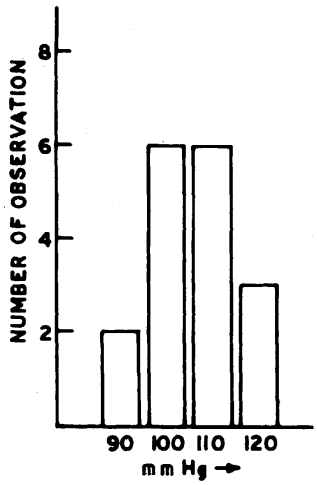
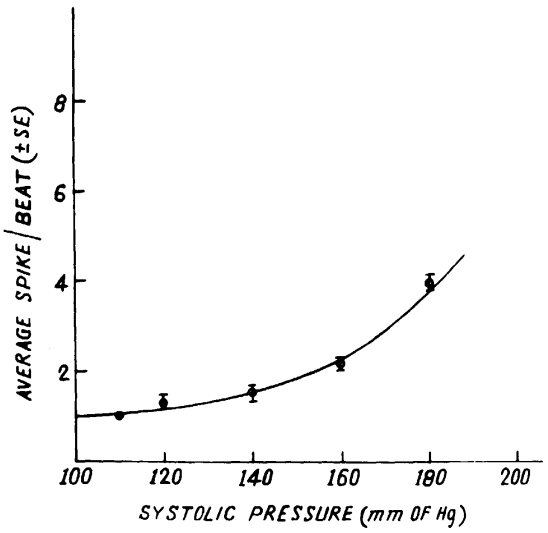


Fig. 5. Histogram showing the number of observations against threshold pressure (at which the spikes start to appear) for 17 single units of Type I receptors.

ERRATA

In the article entitled "High threshold aortic baroreceptors afferents in the sympathetic nerve of monkey" by Biswanath Koley, Pratima Pal, and Juthika Koley in Vol. 39, No. 1, 1989, p. 151: Fig. 6 should be read as follows:



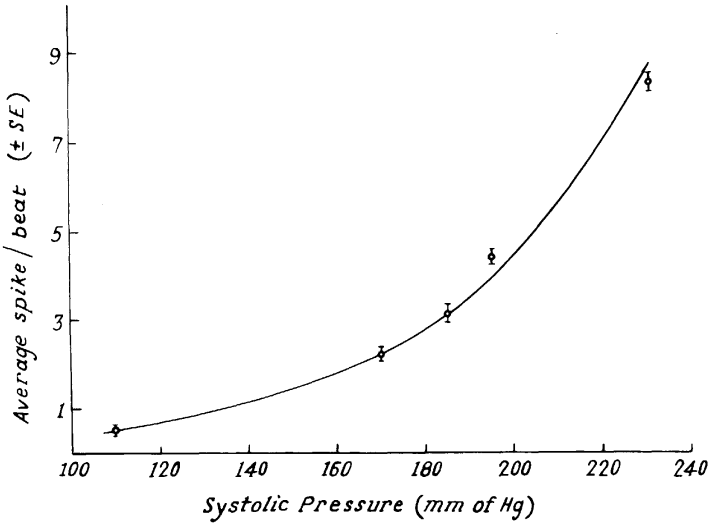


Fig. 6. Average (±S.E.) discharge pattern of ten Type I aortic receptors in monkey against systolic height of blood pressure induced by adrenaline infusion.

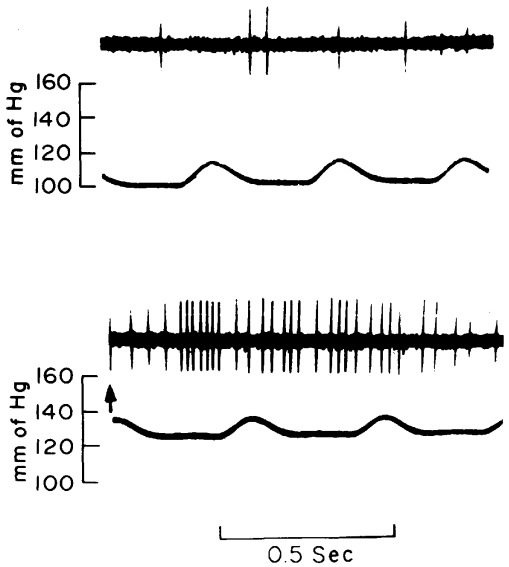


Fig. 7. Response pattern of one spontaneous Type II receptor of monkey to increased aortic pressure. Upper panel shows the spontaneous discharge pattern of Type II receptor, which is asynchronous to heart beat. Lower panel shows the discharge pattern of the same receptor to increased aortic pressure induced by occlusion of the descending aorta. Within the panels, the upper tracing shows the unit discharge and lower tracing shows the arterial pressure.

descending aorta (Fig. 2). These receptors fired irregularly and were mostly asynchronous with the heart beat. When the pressure was raised there was a continuous discharge and unlike Type I receptors described earlier, these Type II receptors did not have interruption during the diastolic phase (Fig. 7). They were excitable with mechanical probing, occlusion of the descending aorta, or increased pressure with adrenaline (10–15 μg/kg) infusion. These receptors did not behave like baroreceptors. The conduction velocity of these afferents was in the range of 1.32 to 2.5 m/s.

DISCUSSION

In the present investigation, it has been possible to show similar types of sympathetic endings in the aorta of monkey, as in the case of cats (KOLEY *et al.*, 1985). Type I receptors localised at the base of the bracheocephalic trunk gave a spike discharge at each systolic height of pressure at about 90 to 120 mmHg. However, sometimes they failed to appear even at such systolic pressure. When the systemic pressure was increased up to 180 mmHg by occluding the descending aorta or by infusing adrenaline solution intravenously, the frequency of discharge of Type I receptors increased up to 4 spikes/cardiac cycle and they behaved exactly like typical sino-aortic baroreceptors (HEYMANS and NEIL, 1958) except for the difference in threshold pressure which was very high (Fig. 5). In the present study, like sino-aortic baroreceptors with sinus and aortic afferent nerves, Type I receptors exhibit a direct relationship between discharge rate and pressure (Fig. 6). Unlike aortic or sinus baroreceptors, these Type I receptors fire only once or sometimes not even once per cardiac cycle at systolic pressure of 90 to 120 mmHg. In normal physiological conditions these receptors are normally not so active. But in high blood pressure condition, these aortic Type I baroreceptors with sympathetic afferents presumably take part in combating the increase of pressure. Thus it may be assumed that the sensation of peripheral haemodynamic information is transmitted through Type I aortic receptors with sympathetic afferents to the spinal cord and supraspinal centre for the maintenance of blood pressure homeostasis even in case of failure of normal activity of the sino-aortic baroreceptors.

There were other sympathetic endings, i.e. Type II receptors, which were distributed mainly over the wall of the descending aorta. These receptors showed irregular discharge and were excited with mechanical probing as well as during occlusion of the descending aorta or infusion of adrenaline intravenously. They did not behave like baroreceptors and therefore they seemed to have no role in blood pressure homeostasis.

The same characteristics of Type I and Type II endings have also been demonstrated in cats (KOLEY *et al.*, 1985). While we have found that the threshold pressure in the case of monkey was 90 to 120 mmHg, the same for the cat as observed by KOLEY *et al.* (1985) was 70 to 110 mmHg. It is apparent that the threshold pressure for the baroreceptor endings with sinus or vago-aortic afferents

(HEYMANS *et al.*, 1931; NEIL, 1954) are comparatively low when compared to that for Type I endings with sympathetic afferents of the aorta in cats (KOLEY *et al.*, 1985) and monkeys.

These high threshold baroreceptor endings of the monkeys, which are more close to those of humans, possibly exist for combating the condition of increased pressure by signalling the pressure sensation to the central nervous system through the spinal cord.

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