Time related characteristics of cardiac systole, diastole, baroreceptor activity and inactivity during vagal stimulation and mild haemorrhage in the dog

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INTRODUCTION

When heart rate (HR) changes, it is mostly due to change in cardiac diastole and less to that in systole (*Henry & Meehan* 1965). Recent studies have suggested that cardiovascular mechanoreceptors inform the central nervous system (CNS) about changes in HR (*Arndt et al.* 1971, *Folkow* 1979, *Hakumäki* 1984). *Arndt* even called that left atrial A-type receptors the key to the "HR clock". Furthermore, a significant correlation between cardiac diastole and baroreceptor inactivity time has been detected in dogs responding with tachycardia but not with bradycardia to i.v. infusion (*Hakumäki* 1984). It is poorly known whether cardiac diastole, systole, baroreceptor activity or inactivity reflect HR changes in different haemodynamic conditions. Consequently, this study was designed to elucidate the correlations between cardiac phases and baroreceptor activity and inactivity during vagal efferent stimulation and mild haemorrhage.

MATERIALS AND METHODS

Ten young laboratory bred beagle dogs, weighing 7.8–12.3 kg were premedicated with morphine hydrochloride (1 mg/kg and 30 min later anaesthetized with i.v. infusion of alpha chloralose (100 mg/kg). The dogs were intubated and ventilated with a respirator using a mixture of oxygen and room air.

Baroreceptor activity was recorded with platinum electrodes from single fibre preparation from the left aortic nerve on the neck. Right vago-sympathetic trunk was exposed on the right side of the neck and stimulation electrodes were placed around the vagal nerve for vagal stimulation experiments. A catheter tip pressure ransducer (Millar model PC-350, Millar instruments, U.S.A.) was introduced to aortic arch through the left femoral artery for the recording of aortic pressure (Fig. 1). Left femoral vein was used to cannulate the vena cava caudalis with polyethylene catheter. This was used for mild haemorrhage (0.4 ml/kg/min).

Blood gas analysis and acid – base balance of the animal was monitored by taking arterial blood samples every half an hour. The ventilation was adjusted to maintain physiological gas values and sodium bicarbonate given, if necessary, to keep normal acid-base balance. Baroreceptor nerve activity and aortic pressure were recorded and stored into Racal 7 DS tape recorder. The data were fed off-line to a PDP Minc Declab23 laboratory computer for calculation of haemodynamic and neural parameters.

The linear relationships between parameters were tested with the least square regression analysis. The difference between two correlation coefficients was tested with a test based on standardized normal distribution. The test statistics used was Fisher's Z-transformation.

RESULTS

Vagal stimulation caused, as expected, a decrease in HR. The increase of cardiac cycle length is mainly due to a change in the duration of cardiac diastole but also the duration of cardiac systole increased significantly. A typical recording of the parameters in a vaginal stimulation experiment is seen in Fig 2. There is a significant linear correlation between the duration of cardiac cycle

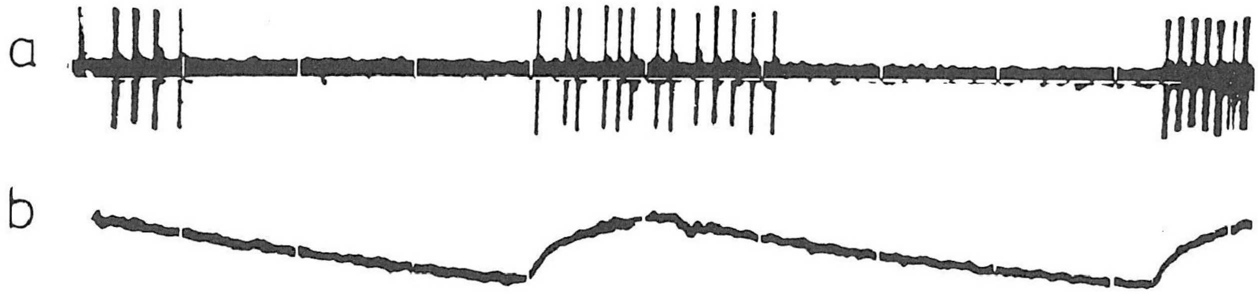

Fig. 1. A typical example of baroreceptor single fibre nerve recording (a) and aortic pressure curve (b).

and the duration of diastole (Table 1). The same was true between the duration of cardiac cycle and duration of systole though the correlation coefficient in this case was significantly lower than that between the duration of cardiac cycle and duration of diastole. There was also a very significant correlation between the duration of cardiac cycle and the duration of baroreceptor inactivity time which was also obvious between the duration of cardiac diastole and duration of baroreceptor inactivity time. The correlation coefficients between the duration of baroreceptor activity and the duration of cardiac cycle or cardiac systole were not so high (Table 1).

In haemorrhage experiments decrease in HR reflected equal decrease in the duration of

Table 1. Vagal stimulation experiments. Correlation coefficients (r) between the duration of cardiac cycle and the duration of diastole (C. cycle/D. diast), of systole (C. cycle/D. syst), of baroreceptor inactivity (C. cycle/D. inact), of baroreceptor activity (C. cycle/D. activ), between the duration of diastole and the duration of baroreceptor inactivity (D. diast/D. inact) and between the duration of systole and duration of baroreceptor activity (D. syst/D. act) in dogs during vagal stimulation. The numbers of cycles (n) are in parenthesis.

Experiment number	C. cycle D. diast r	C. cycle D. syst r	C. cycle D. inact r	C. cycle D. activ r	D. diast D. inact r	D. syst D. act r
1 (n = 218)	0.9982	0.7468	0.7545	0.7580	0.7683	0.7349
2 (n = 358)	0.9983	0.7638	0.9361	0.3849	0.9400	0.4542
3 (n = 297)	0.9979	0.7568	0.9663	0.3420	0.9663	0.4250
4 (n = 222)	0.9903	0.8923	0.8546	0.0123	0.8659	0.1108
5 (n = 241)	0.9771	0.6563	0.7669	0.0347	0.7707	0.0954
6 (n = 278)	0.9955	0.6670	0.921	0.0341	0.9226	0.0341
7 (n = 142)	0.9975	0.6913	0.7571	0.3217	0.7483	0.1213
8 (n = 120)	0.9902	0.6369	0.9822	0.2339	0.9828	0.4403
9 (n = 219)	0.9945	0.8349	0.9900	0.4926	0.9810	0.5584
10 (n = 248)	0.9967	0.9024	0.9937	0.6792	0.9925	0.6846

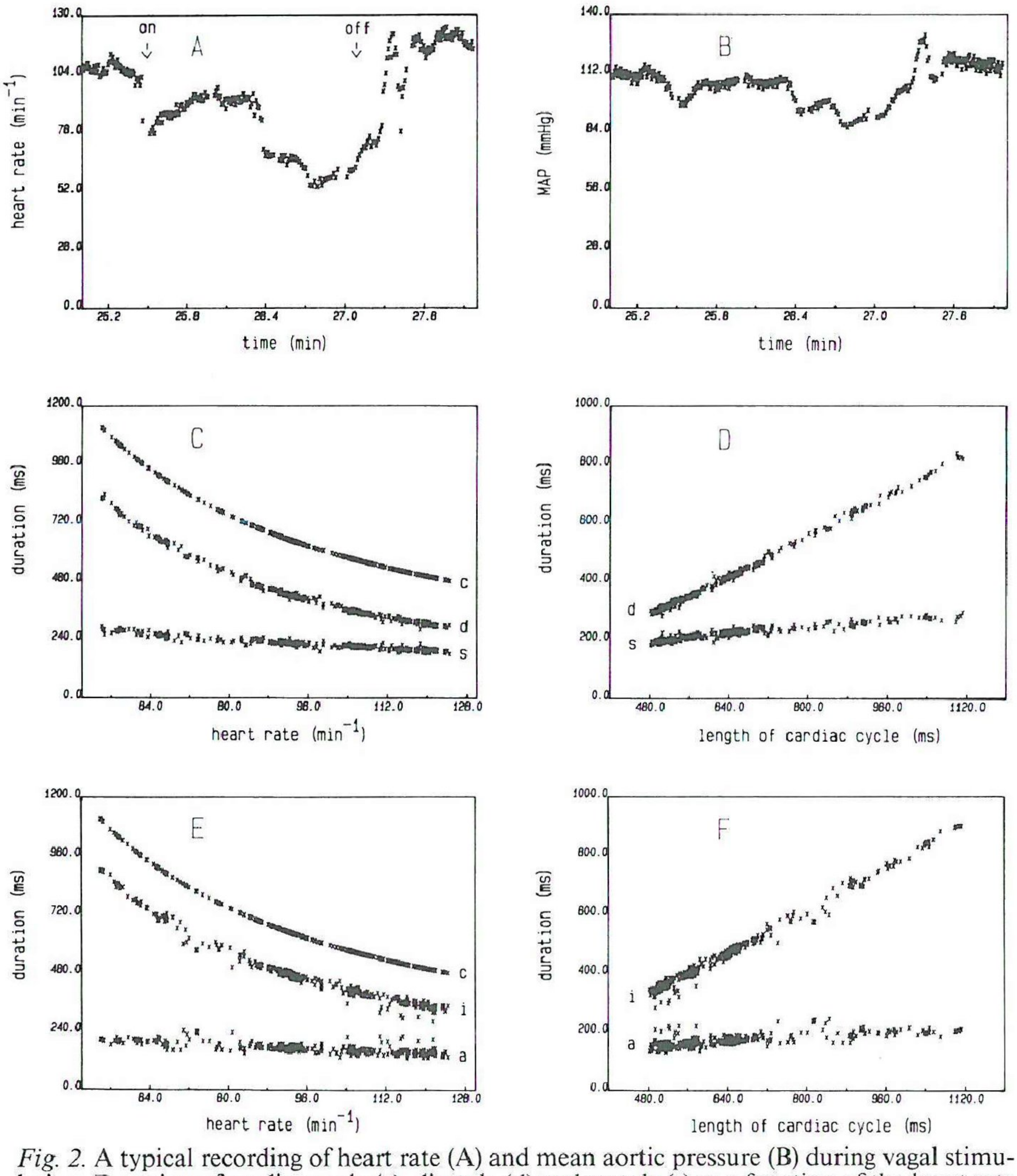

Fig. 2. A typical recording of heart rate (A) and mean aortic pressure (B) during vagal stimulation. Duration of cardiac cycle (c), diastole (d) and systole (s) as a function of the heart rate are presented in C and the duration of diastole (d) and systole (s) as a function of the length of cardiac cycle in D. The length of cardiac cycle (c), baroreceptor inactivity (i) and baroreceptor activity (a) as a function of heart rate are presented in E and duration of baroreceptor inactivity (i) and baroreceptor activity (a) as a function of length of cardiac cycle in F during vagal stimulation in one experimental animal (N:o 10, in tables). Each point represents individual heart cycle. On and off show when the stimulation was started and turned off.

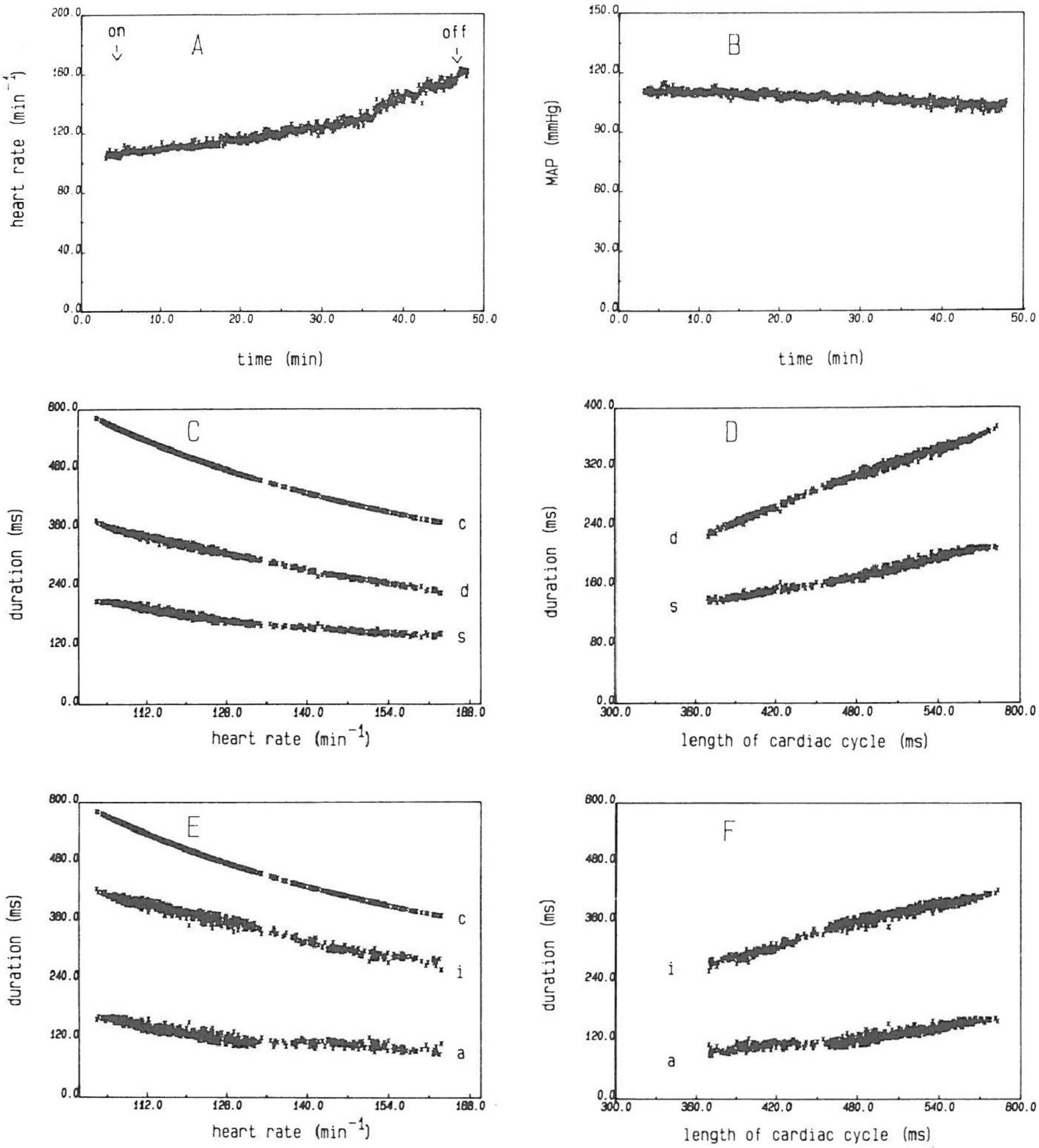

Fig. 3. A typical recording of heart rate (A) and mean aortic pressure (B) during haemorrhage. Ç represents the length of cardiac cycle (c), diastole (d) and systole (s) as a function of the heart rate and i D and the duration of diastole (d) and systole (s) as a function of the length of cardiac cycle. In E is the length of cardiac cycle (c), duration of baroreceptor inactivity (i) and baroreceptor activity (a) as a function of heart rate and in F duration of baroreceptor inactivity (i) and baroreceptor activity (a) as a function of the length of cardiac cycle during mild haemorrhage (0.4 ml/kg/min) in one experimental animal (N:o 10, in tables). Each point represents the mean value of periods of 6 s during a haemorrhage of 45 min.

Table 2. Haemorrhage experiments. Correlation coefficients (r) between the duration of cardiac cycle and the duration of diastole (C. cycle/D. diast), systole (C. cycle/D. syst), baroreceptor inactivity (C. cycle/D. inact), baroreceptor activity (C. cycle/D. activ), between the duration of diastole and the duration of baroreceptor inactivity (D. diast/D. inact) and between the duration of systole and duration of baroreceptor activity (D. syst/D. act) in different cardiac cycles of ten experimental animals during mild haemorrhage (0.4 ml/min/kg for 45 min). The numbers of cycles are in parenthesis.

Experiment number	C. cycle D. diast r	C. cycle D. syst r	C. cycle D. inact r	C. cycle D. activ r	D. diast D. inact r	D. syst D. act r
1 (n = 7820)	0.7902	0.7282	0.6980	0.7486	0.7151	0.4748
2 (n = 5320)	0.9889	0.8836	0.7664	0.8878	0.7786	0.5102
3 (n = 6438)	0.8061	0.6623	0.4246	0.6342	0.4178	0.8528
4 (n = 3400)	0.9858	0.6363	0.8644	0.2791	0.8503	0.7221
5 (n = 2700)	0.7601	0.6937	0.5673	0.2663	0.4312	0.3817
6 (n = 4700)	0.7827	0.6641	0.8617	0.8874	0.4157	0.4068
7 (n = 7251)	0.8891	0.7302	0.8796	0.6758	0.5642	0.9512
8 (n = 6845)	0.4947	0.2319	0.6412	0.7960	0.4461	0.3788
9 (n = 5964)	0.6931	0.7533	0.6396	0.7132	0.6761	0.7634
10 (n = 5629)	0.8970	0.6961	0.7664	0.4226	0.7778	0.5012

both diastole and systole (Fig. 3). A very high linear correlation existed between the duration of cardiac cycle and the duration of cardiac diastole (Table 2). The correlation coefficient between the duration of cardiac cycle and the duration of systole was significantly lower compared to that between duration of cardiac cycle and duration of diastole. The correlation coefficient between the duration of cardiac cycle and the duration of baroreceptor inactivity period was high as well as the correlation coefficient between the duration of cardiac diastole and the duration of baroreceptor inactivity time. The linear correlation coefficients between the duration of baroreceptor activity and the duration of cardiac cycle or cardiac systole were not as high (Table 2).

DISCUSSION

Cardiac systole and diastole are mechanical actions due to the cardiac pump function. Possible information about HR to the CNS is carried from the neural mechanoreceptors by the cardiovascular nerves. Among cardiovascular mechanoreceptors it is the baroreceptor function that is most closely connected to the systole and diastole in their function. They are also the most regularly firing system of the cardiovascular receptors. In physiological state, the baroreceptor inform the CNS about the pressure or distension level of the aorta. Main bulk of the baroreceptor activity occurs during cardiac systole just after the opening of the aortic valve, coinciding with the aortic pressure rise. There are only few baroreceptor fibres after aortic valve closure, i.e. during diastole. Only when aortic pressure rises markedly the baroreceptors start to fire more regularly during diastole.

Increase of vagal efferent activity is an effective tool to decrease HR. It seems that when HR is changed with vagal stimulation there exists a very significant correlation between the duration of cardiac cycle and the duration of the inactivity of baroreceptor firing. The same was true in haemorrhage experiments (Fig. 2, 3, Table 1,2). This implies that by the duration of baroreceptor inactivity the system is able to inform CNS about the duration of cardiac cycle i.e. HR.

In haemorhage HR rises because of increased sympathetic tone to the heart. It seems that the duration of both cardiac systole and cardiac diastole decreases during the haemorrhage.

In this paper, it has been demonstrated that the changes in the length of cardiac cycle during change in HR occur mainly in diastole but systole is also involved. This is obvious both during cardiac vagal stimulation and during haemorrhage where the sympathetic outflow to the heart is increased.

According to the results in this paper, baroreceptor firing is also cabable to inform the CNS about the length of cardiac cycle by changing the duration of the baroreceptor inactivity period during cardiac cycles.

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Summary
The duration of cardiac systole and diastole in each individual cardiac cycle were measured from aortic pressure curves during vagal stimulation and mild haemorrhage with simultaneous recording of aortic baroreceptor single fibre nerve activity. The duration of cardiac diastole was highly correlated with the duration of cardiac cycle in all the interventions. The correlation coefficient between the duration of cardiac systole and the duration of cardiac cycle was not as high as that between the duration of cardiac cycle and cardiac diastole. A highly linear correlation also existed between the duration of cardiac cycle and the duration of baroreceptor inactivity time. The same was true when the duration of baroreceptor inactivity time was compared with the duration of cardiac diastole. It is concluded that the duration of baroreceptor inactivity time may inform the central nervous system about heart rate.

Yhteenveto
Kokeessa mitattiin sydämen toimintakierron systolen ja diastolen kestot aortan painekäytästä vagustimulation ja lievän verenvuodatuksen aikana. samalla rekisteröitiin aortan baroreseptorin aktiviteettia josta mitattiin hermoimpulssien aktiivivaiheen ja inaktiivisuusvaiheen kestot. Edellämainittuja ajallisia suureita tarkasteltaessa voitiin todeta että sydämen diastolen kesto hyvin merkittävästi korreloi sydämen toimintakierron kestoon. Myöskin sydämen toimintakierronja baroreseptoreiden inaktiivisuusajan välillä oli erittäin merkittävä korrelatio. On mahdollista että baroreseptoreiden inaktiivisuuden keston avulla keskushermosto saa tietoa sydämen toimintakierron kestosta.

Sammendrag
I denne undersøgelse af trykvariationer gennem hundens hjertecyklus observeredes en nøje korrelation mellem varigheden af den diastoliske fase med varigheden af hele cyklus.
Korrelationen mellem varigheden af systolen og varigheden af hele cyklus var ikke så høj som mellem varigheden af hjertecyklus og diastollængden.
Der fandtes en høj lineær korrelation mellem længden af hjertecyklus, længden af hjertets diastole og længden af baroreceptorinaktivitetstid.
Det konkluderedes, at længden af baroreceptorinaktivitetstiden måske informerer centralnervesystemet om hjerterate.

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