Measurements and Variability of Arterial Blood Pressure and Heart Interval in Conscious and Anesthetized Dogs

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INTRODUCTION

The majority of the experimental studies in circulatory physiology have been performed with anesthetized animals. General anesthesia affects the circulation not only through direct effects, but also through modification of the integrative response involved (*Vatner* 1978). Moreover, the depth of anesthesia has an effect on cardiac function (*Laver* 1963, *Horwitz* 1977). Major differences in responses of conscious and anesthetized animals are found in circulatory reflexes (*Vatner* 1978). Changes in the depth of anesthesia, in blood gas tension or in the general condition of the animal easily alter the sympathetic and vagal activities and may do so in a different manner or to a varied degree (*Kollai & Koizumi* 1981). Thus, circulatory reflectory functions may also be disturbed in anesthetized animals.

Distension of pulmonary vein-left atrial junction has been used for evaluation of reflectory sensitivity in conscious and anesthetized dogs (*Nevalainen et al.* 1980). The distension was found to enhance tachycardia in conscious and chloralose anesthetized dogs, while in pentobarbital anesthetized dogs the effect was minimal.

Morphine and its derivatives used for anesthetic premedication have sedative and usually vagotonic effects on autonomic neuronal regulation (*Page & Hoff* 1969). In some species and individuals it may cause also excitatory responses. In large doses the vasomotor and respiratory centers are depressed with morphine. In dogs, bradycardia, sighing respiration, increased respiratory arrhythmia and tendency toward atrial fibrillation were observed after morphine administration at a dose of 15 mg/kg (*Page & Hoff* 1969). The dose of 2 mg/kg of morphine induced no significant sustained effect on heart rate or arterial blood pressure, but a transient reduction in cardiac size was observed (*Vatner et al.* 1975). Although morphine is a depressant of neuronal functions, this effect is not uniform. It has been reported to enhance monosynaptic reflexes, whereas multineuronal reflexes are depressed (*Wikler* 1944).

Alpha-chloralose is widely used as an anesthetic agent in experimental cardiovascular and neurophysiological research. It seems to augment the excitability of the spinal cord and some vasomotor reflexes. It has been considered particularly useful for animals, in which autonomic reflexes should be preserved (*Croft* 1964). Mechanoreceptor reflexes controlling heart rate have been found to be exaggerated by chloralose (*Cox* 1972). The induction of anesthesia by chloralose is associated with transient hemodynamic changes for 15 min such as a peripheral vasodilatation, a loss of arrhythmia, tachycardia, myocardial depression and venous pooling. After induction the hemodynamics return to normal (*Cox* 1972) or a tachycardic response may remain (*Bass & Beckley* 1966). In experimental applications, chloralose is often used together with premedication, usually with morphine derivatives. Morphine causes, however, direct and reflectory changes, which may exaggerate or counteract the effect of chloralose (*Cox* 1972).

Pentobarbital is the most commonly used anesthetic agent in experimental animal studies (*Rushmer et al.* 1963). It has been described to induce tachycardia (*Priano et al.* 1969, *Man-*

ders & Vatner 1976, *Halinen et al.* 1978) and decrease (*Manders & Vatner* 1976) or have no effect (*Priano et al.* 1969) on arterial blood pressure. Morphine is often combined with pentobarbital as a premedication and thus they may modify their individual effects. Pentobarbital has an effective vagolytic (*Page & Hoff* 1969) and also sympatholytic (*Halinen et al.* 1978) influence on autonomic nervous system in dogs.

The induction of anesthesia by pentobarbital causes transient alterations in hemodynamics which return after 15 min with the exception that stroke volume is decreased and heart rate increased to a high level during the anesthesia (*Cox* 1972). During normal resting conditions in the healthy dog, there are wide and spontaneous beat-to-beat alterations in cardiac function. These variations and respiratory arrhythmia are abolished by pentobarbital anesthesia (*Van Citters et al.* 1964, *Halinen et al.* 1978). The initial level of heart rate may also have an influence on the level after induction of anesthesia (*Manders & Watner* 1976).

The aim of the present study was to evaluate the effects of the most commonly used anesthetics on arterial blood pressure, heart interval and their variation in dogs. Furthermore, distension of the pulmonary vein-left atrial junction was applied to test the effect of the agents on the reflectory sensitivity of dogs.

MATERIALS AND METHODS

Animals

For the experiments, a total of ten laboratory bred beagles of both sexes (1-1.5 years old), weighing 8-12 kg were used. Before and after the surgical procedures the dogs were accustomed to the restraining harness (*Sine & Englers* 1965) and the laboratory surroundings.

Surgical procedures

All surgical procedures were done under general anesthesia. Induction of the anesthesia and intubation were carried out with thiopental sodium (Hypnostan^{R}, Leiras, Finland). A sterile left thoracotomy was performed through the fourth intercostal space under methoxyflurane (Penthrane^{R}, Abbott, USA) anesthesia and positive pressure ventilation (Engström 150, Mivab, Sweden). For distension experiments a balloon catheter was passed via the pulmonary vein of the left apical lobe to the pulmonary vein-left atrial junction and fixed in place with ligatures around the pulmonary vein. The left apical lobe was ligated and removed. For aortic pressure measurements, a PVC catheter with a curved hypodermic needle on its tip was placed into and out of the descending aorta. The needle was cut off and the proximal end of the catheter was pushed into the lumen of the aorta. The catheter was fixed in place with sutures through the adventitia beneath the cuff of the catheter (*Herd & Barger* 1964), and is was exteriorized identically to the atrial balloon catheter out of the thorax to the left side of the neck.

Postoperative care

Methoxyflurane anesthesia induced postoperative analgesia lasting to the following day. Thereafter small doses of morphine (Morphin^{R} 2%, Medica, Finland) were used for additional postoperative analgesia as required. The animals were allowed to recover for at least four days after the operation before the experiments. The arterial pressure catheter was flushed every two days with a solution of 2% heparin (Heparin^{R} 5000 UI/ml, Medica, Finland) in 0.9% saline in order to prevent clotting.

Experimental design

The experiments were performed in each dog with the following medications:

1. Conscious dogs without medication (CTR).
2. Morphine hydrochloride (Morphin^{R} 2%, Medica, Finland) 1 mg/kg s.c. (MOR).
3. Morphine hydrochloride 1 mg/kg + alpha-D(+)-glucochloralose (Merck, West-Germany) 100 mg/kg i.a. (M + C).
4. Morphine hydrochloride 1 mg/kg s.c. + sodium pentobarbital (Mebunat^{R}, Orion, Finland) 30 mg/kg i.a. (M + P).

Morphine was administered as subcutaneous injection to the interscapular region of the back one hour before the experiment. Other medications were given slowly via the sortic ca-

theter 15 min before each experiment. The experiments were carried out in randomized order so that the effect of sequence in experiments was minimized. Arterial blood pH values were determined before each experiment. No attempt was made to control either respiration, blood gas composition or acid-base balance, because attempts to compensate for such alterations might have added to the complexity of the interpretation of the experimental data (*Cox* 1972).

The experiments were performed in an isolated laboratory, where the background noise was minimized. Each dog was fasted overnight and placed before the experiment in the restraining harness in a horizontal, four leg standing position (*Sine & Englers* 1965). The arterial blood pressure was measured with a pressure transducer (Hewlett Packard 267BC) connected to an amplifier (Hewlett Packard 8805B) and stored into an instrumentation tape recorder (Racal Store 7D).

Before each experiment the dogs were allowed to adapt to the surroundings for at least 10 min. The experiment consisted of two control periods; the first one at the beginning and the second one at the end of the experiment. The distension period, when the atrial balloon was inflated, was between the control periods. The duration of each period was 8 min.

Statistical analysis

The beat-to-beat variation of heart rate and arterial blood pressure parameters were examined from each group of five dogs. the arterial pressure curve was calibrated and plotted off-line (Mingograf 34) as a continuous analogue signal for calculation. In each recording, 60 consecutive intervals of the arterial pressure curve were evaluated two min before and two min after the beginning of the distension. From each arterial pressure peak heart interval, systolic, diastolic and pulse pressures were measured.

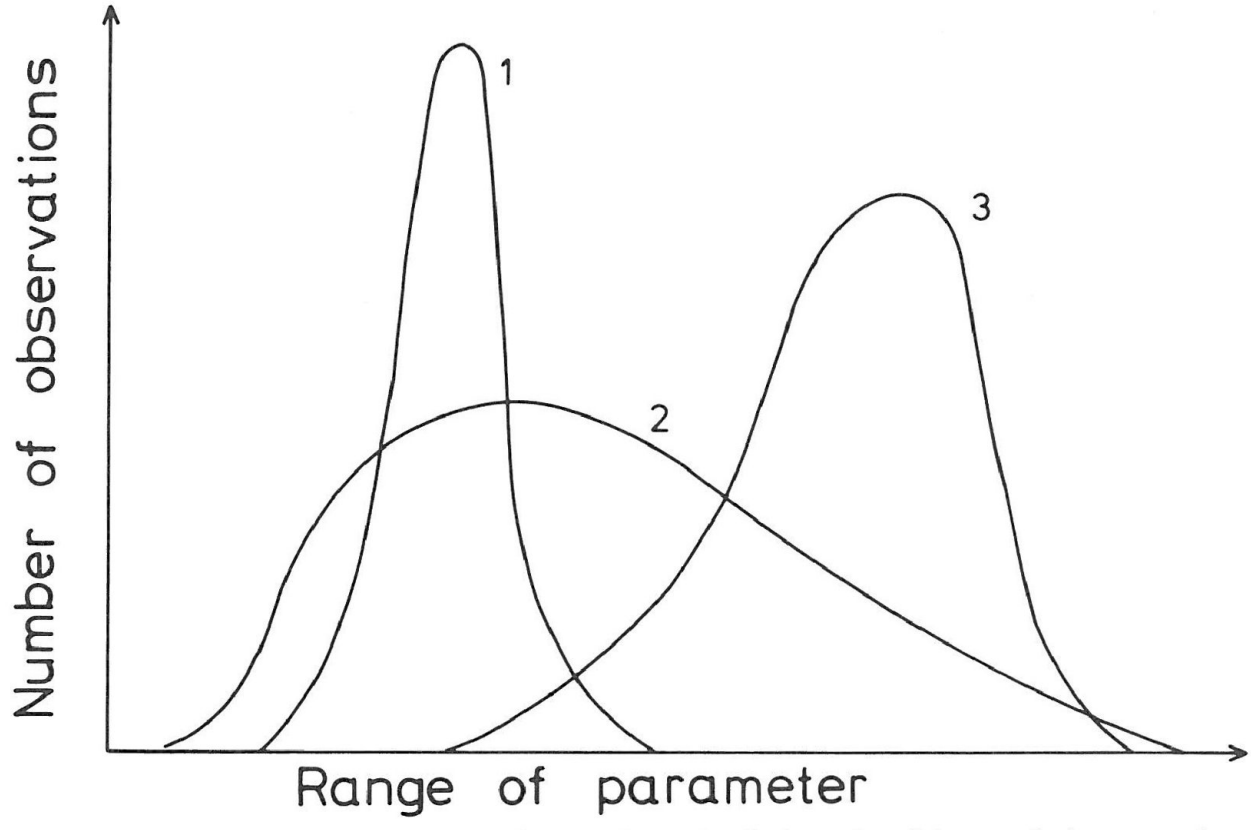

Figure 1. Characterization of the distribution of beat-to-beat values by kurtosis and skewness in three examples: 1) positive kurtosis, normal skewness, 2) negative kurtosis, positive skewness and 3) normal kurtosis, negative skewness.

For statistical analysis the parameters were coded by medication, animal and time in relation to distension. The parameters were transferred to a computer (VAX 11/780) for the statistical analysis (SPSS^x-program, SPSS^x User's Guide). The normality of variable distributions was tested by Kolmogorov-Smirnov test. The significance of the differences between groups was then tested by Mann-Whitney U-test. Kurtosis and skewness of the distributions (Figure 1) in each dog were calculated and the differences between the groups were tested by dividing a difference with its standard error. The test statistics calculated in this way come from standardized normal distribution when null hypothesis is true. Nevertheless, *Snedecor & Cochran* (1980) point out that the distribution of kurtosis does not approach the normal distribution closely in small samples. So the significances for differences in kurtosis are rather indicative.

RESULTS

Effects of morphine, chloralose and pentobarbital

The dogs treated with morphine, chloralose and pentobarbital all had some characteristics, which differed from those of nonmedicated dogs. All the agents caused a significant decrease in arterial blood pH-values (Table 1). Significant differences were also found in arterial blood pressure and heart interval values (Table 2). In conscious dogs, quite large beat-to-beat variation was observed both in arterial blood pressure and heart interval. Since the Kolmogorov-Smirnov test showed that the distribution of the observations was not normal, the Mann-Whitney U-test was used for comparison of groups. Significant differences were found both between groups and inside the groups due to the distension.

Table 1. Arterial blood pH values (mean ± SD) in the experimental groups. Statistical significance of difference in comparison to dogs without medication (CTR) has been calculated using Mann-Whitney U-test. MOR = morphine, M + C = morphine-chloralose and M + P = morphine-pentobarbital treated dogs.

Group	pH	N	Significance
CTR	7.44 ± 0.03	8	
MOR	7.35 ± 0.07	14	$p < 0.001$
M + C	7.32 ± 0.10	4	$p < 0.05$
M + P	7.31 ± 0.08	4	$p < 0.01$

Morphine had no significant effect on systolic pressure, while diastolic pressure was lowered, and pulse pressure and heart interval values increased. Morphine-chloralose combination decreased both heart rate and all pressure parameters when compared to the nonmedicated dogs. Both systolic and diastolic arterial pressure decreased and while the change in systolic pressure was greater, pulse pressure was also decreased. Morphine-pentobarbital combination caused tachycardia and decreased beat-to-beat variation in all of the animals. The pressure parameters were decreased as in the morphine-chloralose anesthetized dogs, pulse pressure even to half of the value observed in conscious dogs.

Effect of distension

The effect of distension was somewhat different with all the medications used (Table 2). In conscious dogs systolic pressure increased significantly, so that pulse pressure decreased. Moreover, a significant tachycardic response was induced. In morphine medicated dogs, the stimulation induced a significant decrease in all arterial blood pressure parameters, but in heart interval the change was minimal. With the combination of morphine and chloralose, the stimulation elicited an increase in systolic and diastolic pressure, while pulse pressure and heart interval decreased. With the combination of morphine and pentobarbital, the changes induced by the stimulation were minimal; only a slight decrease in systolic and diastolic pressure, while no changes in heart rate was observed.

Differences in kurtosis and skewness

The differences in kurtosis and skewness between the groups without and with left atrial mechanoreceptor stimulation are expressed in Tables 3 and 4.

Kurtosis (i.e. sharpness of the distribution curve) of the cardiovascular data remained practi-

Table 2. Effect of different medications on systolic (Psyst), diastolic (Pdiast), pulse pressure (PP) and heart interval (HI), and the changes induced by distension of pulmonary vein-left atrial junction in dogs. The values (mean ± SD) are given before and during the distension. Number of dogs = 5 and number of observations in each group = 300. Significances between the means are calculated with Mann-Whitney U-test.
pc: significance in comparison to nonmedicated dogs (CTR),
pd: significance of distension response,
ns = not significant, * = $p < 0.05$, ** = < 0.01, *** = $p < 0.001$. For other abbreviations see Table 1.

Medication / Period / P	Psyst (kPa)	Pdiast (kPa)	PP (kPa)	HI (ms)
CTR				
before	23.8 ± 1.5	14.6 ± 2.0	9.3 ± 1.6	616 ± 136
pc				
during	24.1 ± 1.8	15.5 ± 1.9	8.5 ± 1.8	523 ± 100
pd	ns	***	***	***
MOR				
before	23.9 ± 1.5	13.6 ± 1.8	10.2 ± 1.8	902 ± 240
pc	ns	***	***	***
during	22.7 ± 1.5	12.9 ± 2.1	9.8 ± 1.4	881 ± 249
pd	***	***	**	ns
M+C				
before	16.0 ± 1.4	9.3 ± 1.9	6.7 ± 1.0	848 ± 202
pc	***	***	***	***
during	16.6 ± 1.3	10.4 ± 2.0	6.2 ± 1.2	665 ± 229
pd	***	***	***	***
M+P				
before	16.3 ± 0.9	10.8 ± 0.7	5.5 ± 0.9	384 ± 47
pc	***	***	***	***
during	16.2 ± 0.9	10.4 ± 0.5	5.7 ± 0.8	383 ± 49
pd	*	***	ns	ns

Table 3. Modifications in kurtosis of systolic, diastolic, pulse pressure and heart interval by different medications and distension of pulmonary vein-left atrial junction in dogs. The numbers indicate how many out of 5 dogs had significant change ($p < 0.05$) in kurtosis of each parameter. For abbreviations see Tables 1 and 2.

Medication / Period	Psyst	Pdiast	PP	HI *
CTR				
before	0 - level for measurements			
during	0	0	1 inc	0
MOR				
before	2 inc	3 inc	2 inc	2 inc
during	3 dec	3 dec	1 inc	1 dec
M+C				
before	0	0	2 inc	0
during	0	2 inc	1 inc/1 dec	0
M+P				
before	0	0	1 inc	2 inc
during	2 inc	0	0	1 inc/1 dec

*) inc = increased, dec = decreased kurtosis

Table 4. Modifications in skewness of systolic, diastolic, pulse pressure and heart interval by different medications and distension of pulmonary vein-left atrial junction in dogs. The numbers indicate how many out of 5 dogs had significant change ($p < 0.05$) in kurtosis of each parameter. For abbreviations see Tables 1 and 2.

Medication / Period	Psyst	Pdiast	PP	HI	*
CTR					
before	0 - level for measurements				
during	0	1 dec	1 inc/1 dec	0	
MOR					
before	2 inc/1 dec	3 inc/1 dec	1 inc/1 dec	3 dec	
during	1 inc/2 dec	1 dec	1 dec	0	
M+C					
before	1 inc	2 inc	0	1 dec	
during	0	2 dec	3 inc/1 dec	1 inc	
M+P					
before	1 inc	0	2 inc	1 inc/1 dec	
during	0	0	0	2 dec	

*) inc = increased, dec = decreased skewness

cally unchanged during the distension in conscious dogs. In morphine medicated dogs, kurtosis was increased in 2-3 of 5 dogs, while during distension the tendency was rather reversed. In morphine-chloralose anesthetized dogs, the differences were smaller; only in pulse pressure of control state and in diastolic pressure during distension was the kurtosis increased significantly in two out of 5 dogs. In morphine-pentobarbital anesthetized dogs, an increase of kurtosis was found in pulse pressure and heart interval during control state, and in systolic blood pressure during distension.

In practice, the increase of kurtosis commonly found in the medicated dogs means a decrease of beat-to-beat variation of hemodynamic parameters. During distension, the effect of medications was mainly decreasing in diastolic pressure, while in other parameters it was bidirectional.

Skewness (i.e. asymmetry of the data distribution) changed in conscious dogs during distension only in diastolic and pulse pressure in few dogs. In morphine and morphine-chloralose medicated dogs, the changes were more general. In morphine-pentobarbital anesthetized dogs, significant changes were found in some dogs during control state, but during distension only the skewness of heart interval was changed in two dogs.

DISCUSSION

Training

Training of the conscious experimental animals was considered an essential part of the experiments as the dog was accustomed to the experimenter, surroundings and measurement methods. It seems also, that calm and planned training reduces the need for severe restraint of the animal. As a matter of fact the handling of the dog, e.g. patting and feeding, can be used as a means for conditioning its behavior.

Laboratory bred beagles are usually very easy to handle and train. In the present study none of the dogs was non-adapted for the measurements. Some of the experiments with restraining harness lasting up to half an hour were terminated because of movement of the dog and they were carried out later after a new adaptation period.

Instrumentation

The method of *Herd & Barger* (1964) for catheter implantation proved safe and relatively easy

to use in dogs. An important advantage of this method is that all necessary catheters can be placed through the thoracic incision. Dissecting the neck area for arterial catheterization may easily damage other structures, e.g. nerves, and carotid clamping abolishes the baroreceptor function in that area.

The health condition of an animal has been found to affect the cardiovascular experimental data (*Giles & Burch* 1970). Thus normal health of the dog was required for the experiments. The catheters, protective collar and their fastening were examined every other day. The role of experienced personnel of the laboratory animal center was fundamentally important in observing and estimating the condition of chronically instrumented dogs. After the recovery period, no severe postoperative complications were observed.

Restraint

A restraining harness (*Sine & Englers* 1965) was used for both conscious and anesthetized dogs. The harness with a support for the head made it possible to keep the dog exactly in the same position in all of the experiments. Movements of the animal were allowed to a moderate degree with the reservation that the measurements were not disturbed.

Heart rate and blood pressure recordings

The arterial pressure vs. heart interval relationship can be used for estimating two different events in the cardiac cycle. Firstly, while each heart interval regulates the diastolic filling of the ventricle, each pressure wave can be considered as a result of the preceding time pattern. In addition to atrial function, also changes in ventricular stiffness may change the efficiency of filling. In the work of *Templeton et al.* (1975), many factors including myocardial ischemia, propranolol medication and pentobarbital anesthesia changed the ventricular stiffness properties. Also in the present study, the medications seemed to change the diastolic filling phase of the left ventricle, when estimated as en effect of the preceding heart interval on the pressure.

Secondly, the relationship between each pressure wave and the heart interval thereafter can be used as a measure of sensitivity of the arterial baroreceptor reflex (*Sleight* 1980). This relationship has been found to change in many conditions, e.g. in sleep, exercise, anxiety and change of posture (*Sleight* 1980). In dogs, the impulses from one pressure wave can influence the heart before the next beat, at heart rate lavels less than 160 b/min, since the latency of this event in dog is about 380 ms (*Jewett* 1964).

Distension of pulmonary vein-left atrial junction

The distension of pulmonary vein-left atrial junction was used as a standardized stimulation of the autonomic reflex system. The stimulation of left atrial receptors by the distension causes an activation of sympathetic cardiac efferentation and an increase in heart rate (*Hakumäki* 1979), which is abolished in cardiac-denervated dogs (*Fater et al.* 1982). A tachycardic response was elicited by distension also in the present work with conscius dogs. Accordingly the results are similar to earlier studies on conscious dogs with one small balloon (*Nevalainen et al.* 1980). Also in anesthetized dogs the same response has been observed (*Ledsome & Linden* 1964, *Edis et al.* 1970, *Kollai et al.* 1978, *Chapman et al.* 1978), though it is weaker in pentobarbital anesthetized dogs (*Nevalainen et al.* 1980).

Consciousness vs. anesthesia

The use of conscious animal models has an important role in physiological experimentation, when the function and interactions of organ systems in intact conditions are documented (*Priano et al.* 1969, *McDonald* 1980).

Chloralose and pentobarbital are the most commonly used anesthetics in physiological research on dogs. The impact of these compounds on the results and conclusions is commonly disregarded. This may be due to the fact that the circulatory and autonomic effects of anesthetics are poorly known (*Manders & Watner* 1976) and that their direct and indirect ef-

fects are difficult to differentiate (*Horwitz* 1977). Therefore one purpose of this study was to compare the dogs in the conscious and anesthetized state.

Acidosis in anesthetized, surgically traumatized animals may be an important factor contributing to the variation in results from investigations regarding cardiac reflex functions (*Harry et al.* 1971). Also in the present work, arterial pH values were lowered during anesthesia to an extent that changes in reflectory reactivity are possible.

The body temperature usually decreases during anesthesia, which again may have effects on reflex functions and the overall condition of the animal. On the other hand, chloralose may elevate transiently the body temperature, since it is administered as a copious and warm infusion to prevent sediment production.

In these results, the most prominent effect of morphine was a decrease in heart rate. Since chloralose or pentobarbital was administered after morphine, those results must be considered as a combined effect of morphine with these agents. Both combinations induced marked hypotension. Morphine-chloralose affected heart rate minimally, while morphine-pentobarbital induced tachycardia. From this difference it can be concluded that the effect of morphine in these combinations was relatively small. However, morphine alone at the same dose had a clear sedative effect on the behaviour of the dogs.

Changes in kurtosis and skewness

In addition to the level of parameters, also significant differences in the kurtosis and skewness were found between the treatments. Fluctuation of heart interval i.e. sinus arrhythmia is generally quite large in conscious dogs. All the medications studied, and pentobarbital in particular, changed the sinus arrhythmia in relation to the conscious state. These differences were found also without any changes in the level of the parameters. Therefore it seems, that kurtosis and skewness of the cardiovascular data can be used for assessing the »normality« of the circulation. The anesthetics studied had clear effects on the distribution, which obviously is mainly related to changes in respiratory-induced variation of the circulation. In heart rate this was seen as changes of sinus-arrhythmia, but in blood pressure the similar characteristics could be found.

As a whole, all the agents studied had significant effect on the level and variation of heart rate and arterial blood pressure in dogs. Therefore, in future special emphasis should be paid on the use of trained, chronically instrumented and conscious dogs in cardiovasular research.

Sammendrag

Syftet med denna undersökning var att jämföra cirkulationsregleringen hos medvetna och nedsövda hundar. För detta ändamål utvecklades en kroniskt instrumenterad, medveten försöksdjurmodell. Försöksdjuren vandes vid laboratorieförhållandena före den egentliga undersökningen. På tio hundar placerades i narkos en kateter för tryckmätning i aorta och en dilatationskateter för stimulering av vänster förmak. Införingsstället på halsen hölls under skyddskrage under provserien. Proven inleddes 4 dagar efter operationen.

Blodtrycket registrerades såväl medan vänstra förmaket stimulerades som utan stimulering. Registreringen utfördes i randomiserad ordning utan medicinering resp med morfin- (0.5 mg/kg), morfin-chloralos- (100 mg/kg) och morfin-pentobarbitalmedicinering (30 mg/kg). Från registreringen sammanställdes systoliskt, diastoliskt och pulstryck, pulsintervall samt excess och snedhet i dessas distribution.

Alla de undersökta medlen förändrade signifikant blodtrycket och pulsen i jämförelse med kontrollsituationen. Stimulering av vänster förmak orsakade takykardi och sänkning av blodtrycket hos de djur som inte fått medicinering. Denna respons förblev nästan oförändrad vid morfin-chloralosanestesi men försvagades vid annan medicinering. I parameterdistributionen konstaterades signifikanta excess- och snedhetsförändringar vid alla medicineringar både med och utan stimulering.

Enligt resultaten förändrar de vanligaste narkosmedlen signifikant cirkulationens tillstånd och reflektoriska känslighet. Med hjälp av en kroniskt instrumenterad och medveten försöksdjursmodell kan de av narkos och akut försökssituation framkallade circulationsförändringarna undvikas.

Yhteenveto

Tutkimuksen tarkoituksena oli verrata verenkierron säätelyä tajuisilla ja nukutetuilla koirilla. Tätä varten kehitettiin kroonisesti instrumentoitu, tajuinen koe-eläinmalli. Koe-eläimet totutettiin laboratorio-

olosuhteisiin ennen varsinaista tutkimusta. Kymmenelle koiralle asetettiin yleisanestesiassa paikoilleen aortan painemittauskatetri ja vasemman eteisen stimulaatioon käytetty venytyskatetri. Katetrien ulostulo pidettiin kaulalla suojakauluksen alla koesarjan aikana. Kokeet aloitettiin 4 vuorokautta leikkauksen jälkeen.

Koirilta rekisteröitiin verenpaine sekä ilman vasemman eteisen stimulaatiota että sen aikana. Rekisteröinti suoritettiin satunnaistetussa järjestyksessä ilman lääkitystä sekä morfiini- (0.5 mg/kg), morfiini-kloraloosi- (100 mg/kg) ja morfiini-pentobarbitaalilääkityksen (30 mg/kg) kanssa. Rekisteröinnistä tulostettiin systolinen, diastolinen ja pulssipaine, sykeväli sekä näiden jakaumien huipukkuus ja vinous.

Kaikki tutkitut aineet muuttivat merkitsevästi verenpainetta ja sykettä lääkitsemättömään tilanteeseen verrattuna. Vasemman eteisen stimulaatio aiheutti lääkitsemättömillä eläimillä takykardian ja pulssipaineen alentumisen. Tämä vaste säilyi morfiini-kloraloosi-anestesiassa lähes muuttumattomana, mutta vaimentui muilla lääkityksillä. Muuttujien jakaumassa todettiin merkitseviä huipukkuus- ja vinousmuutoksia kaikkien lääkitysten yhteydessä sekä ilman stimulaatiota että sen aikana.

Tulosten perusteella tavallisimmat anestesia-aineet muuttavat koiralla merkitsevästi verenkierron tilaa ja reflektorista herkkyyttä. Kroonisesti instrumentoidun ja tajuisen koe-eläinmallin avulla voidaan välttää anestesian ja akuutin koetilanteen aiheuttamat verenkiertomuutokset.

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