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COMPARATIVE STUDY ON TWO OPERATIVE METHODS FOR TREATMENT OF ACUTE ABDOMINAL SEPSIS IN THE DOG. II. ELECTROCARDIOGRAPHIC DATA, ACID-BASE AND ELECTROLYTE STATUS

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Summary

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The experiment was performed with 2 groups mixed-breed dogs from both sexes, aged 2-5 years, weighing 18.0 ± 1.1 kg (n=6) and 13.3 ± 1.8 kg (n=7) respectively. They were subject to an experimental model of peritonitis, provoked via the creation of an ischemic intestinal loop (Rosato et al., 1972) following general anaesthesia. After 18 hours, an operative inspection for removal of the necrotized intestinal segment was performed and treatment using two approaches was initiated. In one of the groups a laparostoma was created, and in the other – the zipper technique was applied.

In both groups, an ECG study was done immeditely prior to the creation and 24 hours after the removal of the ischemic intestinal loop. Simultaneously, the acid-base parameters, blood electrolytes, LDH activities and the changes in body temperature, heart and respiratory rates were also determined.

The clinical signs accompanying the appearance of acute abdomen were significantly increased body temperature in the zipper technique group, a temperature within the normal range in the laparostoma group and enhanced respiratory rates in both groups.

It was found out that in peritonitis, treated by the zipper technique, the impaired electrical activity of the heart was manifested by ST depression, T wave depression and inversion and shorter diastole with increased systolic index. In dogs treated by laparostoma, ECG changes were predominantly manifested by shortening of all intervals with exception of the QRS complex and a weaker ST depression.

Blood gas and acid-base determinations were characterized by increased pO_2, SAT and O_2CT values in the zipper group compared to the laparostoma group. Electrolyte changes consisted in decreased plasma potassium levels in the laparostoma group vs the zipper group and higher inorganic phosphate concentrations in the zipper group vs the open abdomen technique. The microbiological findings in the peritoneal exudate were positive for *E. coli* and *Proteus sp*.

The studies suggested that the laparostoma technique preserved the myocardium from the toxic effect of bacterial toxins, accumulated within the abdomen and thus, it could be a technique of choice for the treatment of acute abdominal problems.

Key words: dog, ECG, laparostoma, peritonitis, zipper technique

INTRODUCTION

The clinical cases of ileus and acute peritonitis accompanied with endotoxaemia, metabolic acidosis, impaired blood gas exchange and electrolyte disbalance influence directly the heart's electric activity. Cardiovascular effects are provoked by

the hypovolemic and endotoxic shock, electrolyte disturbances, increase in total acidity and a severe oxygen deficiency (Hosgood, 1986; Ivanov et al., 1990). The alterations correlate with time, changing rapidly and extensively. Such a correlation is reported in humans (Tomov, 1986), ruminants and swine (Kostov, 1995; Athawale et al., 1989).

The aim of the present study was to follow out the changes in electrocardiograms in dogs with experimental peritonitis and their relationships with blood gas and electrolyte changes with regard to the influence of two operative methods for treatment of the acute abdomen syndrome upon the elecrical activity of the heart.

MATERIALS AND METHODS

The experiment was performed on 13 mixed-breed dogs from both sexes, aged 2-5 years. They were divided into two groups with 6 dogs (weighing 18.0 ± 1.1 kg) and 7 dogs (weighing 13.3 ± 1.8 kg) respectively. All dogs were submitted to general anaesthesia with halothane (Narcotan, Spofa, Czech Republic) and surgical intervention in order to create an ischemic intestinal loop (IIL) and thus, an experimental model of peritonitis (Rosato, 1972).

Eighteen hours later, after *i.v.* analgesia with 0.01 mg/kg m. fentanyl citrate (Stobium®, The Chemical Pharmaceutical Research Institute, Bulgaria), an operative revision was performed in both groups.

In the dogs from group I (zipper group) the IIL was removed, the abdominal cavity was washed once with warm physiological saline containing 40 mg/kg m. cloxacillin (Cloxacillin®, Antobiotic Co, Bulgaria) and was closed by a zipper, previously sutured to *m. rectus abdominis.*

The dogs from group II (laparostoma group) were treated similarly and a temporary opening (laparostoma) was created with an Ampoxen® polycaproamide mesh and Polycon® suture material (Dinev et al., 2000). Immediately prior to the operative revision, peritoneal exudate for microbiological study was obtained.

In both groups, a functional ECG study was performed with a microprocessor single-channel electrocardiograph (MAIMEX-ECG 1222 ASB) prior to an 24 hours after the creation of the IIL. Six leads were registered:3 standard and 3 augmented in right lateral recumbency using a thermal ECG paper at a rate of 50 mm/s. The trunk points of elecrode attachements were used (Kostov, 1995) that coresponded to limb points in humans, because of the higher voltage. The waves (mV) and intervals (s) were measured using the II standard lead. ECG changes between the various leads were compared.

The systolic index was calculated according to the equation SR = QT/RR × 100 %.

At same time intervals, acid base and blood gas parameters (pH, pO_2, pCO_2, SAT, O_2CT, TCO_2, HCO_3, ABE, SBE, SBC) were measured with an acid-base analyser (ABL-3, Radiometer, Denmark). Blood electrolytes (Na, K, Cl – by atom absorption spectrophotometry; Ca and P – with diagnostic kits of Human Diagnostica, Germany); the body temperature and respiratory rate (by routine methods), the heart rate (on ECGs), plasma LDH activities (with a diagnostic kit of Human Diagnostica, Germany) were determined too.

The data were compared within and between groups using the ANOVA statistical test.

RESULTS

ECGs of experimental animals in the preoperative period (baseline) showed a normal sinus rhythm with heart rates

within the reference ranges (Fig. 1A). No extrasistoles were detected prior to or following peritonitis development. According to QRS direction in leads I and II it was stated that heart's electrical axis was in a normal position. The semi-horizontal electrical position of the heart was maintained after the experimental peritonitis in both groups. The R peak amplitudes in the three standard leads (R1>R2>R3) and the low voltage of P, T waves and QRS complexes in the aVF leads suggested that it was semi-horizontal.

After the development of peritonitis, in both groups there was a significant shortening of cardiac cycles (R-R) vs the baseline duration of 0.54 ± 0.04 s (Table 1) with bigger differences in the zipper technique group (0.31 ± 0.06 s; $p<0.001$) than in the laparostoma group (0.39 ± 0.05 s, $p<0.01$). Both the shape and the amplitude of the R peak did not show statistically significant deviations in operated animals. The atrioventricular interval PQ was shortened in dogs from both groups (0.089±0.010 s in the zipper group, $p<0.05$ and 0.082±0.003 s in the laparostoma group, $p<0.05$) compared to baseline (0.097±0.005 s). The height of the Q wave (septal activation) was negative, with low amplitude or was not registered on ECGs. The height of the R wave, indicative for myocardial ventricular activation, was with a normal height, positive voltage in lead II, monophasic, symmethrical, without irregularities. QRS duration was bigger both in groups I and II (0.065 ± 0.06 s and 0.060 ± 0.001 s respectively, $p<0.01$) compared to baseline (0.044 ± 0.002 s). The S wave, reflecting the stimulation of the end part of right ventricular wall was negative, with low amplitude.

The biggest abnormalities were detected in T waves and ST segments. Low-amplitude and inverted T-waves was no-

Table 1. Results from ECG measurements in dogs with experimental peritonitis, provoked by creation of ischemic intestinal loop (IIL) and treated using two operation techniques 24 hours after IIL creation. Data are presented as mean ± SEM

Parameter	Units	Baseline (n=13)	Zipper technique (n=6)	Laparostoma technique (n=7)
P wave	amplitude,mV duration, s	0.160±0.020 0.053±0.003	0.340±0.070 0.070±0.010	0.190±0.020 0.060±0.003
PQ interval	duration, s	0.097±0.005	0.089±0.010*	0.082±0.003*
QRS complex	duration, s	0.044±0.002	0.065±0.006**	0.060±0.001**
R peak	amplitude,mV	1.073±0.070	0.975±0.130	0.985±0.100
S peak	amplitude,mV	-0.11±0.030	-0.220±0.070	-0.190±0.040
T wave	amplitude,mV duration, s	0.200±0.050 0.070±0.007	-0.200±0.190* 0.050±0.010*	0.230±0.110$^{\#}$ 0.080±0.010$^{\#}$
ST segment	amplitude,mV duration, s	0.017±0.029 0.087±0.009	- 0.048±0.023* 0.040±0.016*	-0.012±0.013*$^{\#}$ 0.051±0.009*
QT interval	duration, s	0.220±0.005	0.165±0.028	0.202±0.013
RR interval	duration, s	0.540±0.040	0.310±0.060***	0.390±0.050**
Systolic index	%	40.74±0.013	53.22±0.06***	51.790±0.005***$^{\#}$

*$p<0.05$, **$p<0.01$, *** $p<0.001$ vs baseline; $^{\#}p<0.05$ between groups.

Table 2. Acid-base and blood gas measurements in dogs with experimental peritonitis, provoked by creation of ischemic intestinal loop (IIL) and treated using two operation techniques 24 hours after IIL creation. Data are presented as mean ± SEM

Parameter	Baseline (n=13)	Zipper technique (n=6)	Laparostoma technique (n=7)
pH	7.243±0.017	7.256±0.033	7.276±0.028
PCO_2, kPa	6.29±0.43	5.85±0.25	6.16±0.39
PO_2 , kPa	6.90±1.03	15.23±7.13***	5.49±0.89$^{\#\#\#}$
HCO_3, mmol/l	19.0±0.9	18.2±1.1	20.3±0.4
TCO_2, mmol/l	20.3±1.0	19.3±1.1	21.6±0.4
ABE, mmol/l	-7.2±0.9	-7.2±0.9	-5.4±0.8
SBE, mmol/l	-6.7±0.9	-7.1±1.5	-5.3±0.6
SBC, mmol/l	18.0±0.7	18.7±1.2	19.3±0.8
SAT, %	62.1±8.1	94.7± 4.0*	58.0±11.7$^{\#}$
O_2CT, vol.%	9.4±1.3	18.0±2.2**	9.4±2.0$^{\#\#}$

*p<0.05, **p<0.01, *** p<0.001 vs baseline; $^{\#}$p<0.05, $^{\#\#}$ p<0.01,$^{\#\#\#}$ p<0.001 between groups.

ticed (Fig. 1B) in the zipper group (-0.20± 0.19 mV) vs baseline (0.20 ± 0.05 mV, p<0.05) and vs the laparostoma group (0.23 ± 0.11 mV, p<0.05). Its duration followed a similar pattern of change, being 0.070 ± 0.007 s prior to the experiment, 0.050 ± 0.009 s in the zipper group (p<0.05 vs baseline) and 0.080 ± 0.01 s in the laparostoma group (p<0.05 vs the zipper group). The T wave shape was asymmetric, with a smooth top and in some cases, biphase. The ST segment was significantly shortened in both experimental groups (0.04 ± 0.016 s and 0.050 ±0.009 s in the zipper and laparostoma groups respectively) compared to baseline (0.087± 0.009 s, p<0.05). The ST segment was under the isoelectrical line in the zipper group (– 0.048±0.023 mV vs the control measurement of 0.017±0.029 mV; p<0.05); i.e. a ST depression was present (Fig. 1C). The ST depression in the laparostoma group was lower (-0.012 ± 0.013 mV, p<0.05 vs both baseline and the other group). The QT interval (ventricular activation and recovery) was not changed. The systolic index was elevated in both groups (53.22±0.06 % and 51.790±0.005 % in groups I and II respectively; p<0.001 vs baseline values of 40.740±0.013%). The between-group difference was significant at p<0.01. An U wave was not detected in all dogs.

The blood gas and acid-base analysis revealed deviations in oxygen metabolism (Table 2). When the closed abdomen technique was applied, venous blood gas parameters were significantly higher than baseline (15.23±7.13 kPa vs 6.90+1.03 kPa; p<0.001 for pO_2; 94.7 ± 4.0% vs 62.1+ 8.1%; p<0.05 for SAT and 18.0 ± 2.2 vol% vs 9.4+1.3 vol% for O_2CT). These values were also significantly higher than the respective measurements in the laparostoma group (5.49±0.89 kPa at p<0.001; 58.0 ± 11.7 % at p<0.05 and 9.4 ± 2.0 vol% at p<0.01 for pO_2, SAT and O_2CT respectively).

Table 3. Plasma electrolytes in dogs with experimental peritonitis, provoked by creation of ischemic intestinal loop (IIL) and treated using two operation techniques 24 hours after IIL creation. Data are presented as mean ± SEM

Parameter	Baseline (n=13)	Zipper technique (n=6)	Laparostoma technique (n=7)
K, mmol/l	4.11 ± 0.13	4.38 ± 0.35	3.51± 0.09$^{\#}$
Na, mmol/l	148 ± 2	147 ± 3	144 ± 2
Cl, mmol/l	109 ± 1	109 ± 2	106 ± 2
Ca, mmol/l	2.57 ± 0.12	2.39 ± 0.17	2.47 ± 0.31
P, mmol/l	1.68 ± 0.08	2.01 ± 0.16	1.37 ± 0.06$^{\#\#}$

$^{\#}$ $p<0.05$, $^{\#\#}$ $p<0.01$ between groups.

Blood electrolytes (Table 3) showed a decrease in the concentrations of one of the most important ions - K^+ in the dogs with laparostoma compared to dogs treated with the zipper technique (3.51±0.09 mmol/l vs 4.38 mmol/l; $p<0.05$). Similar changes were observed in inorganic phosphate levels – 1.37±0.06 mmol/l in dogs with open abdomen vs 2.01±0.16 mmol/l in dogs with closed abdomen, $p<0.01$. The blood concentrations of the other studied electrolytes were not significantly altered.

Lactate dehydrogenase acivity was considerably elevated in the zipper group (777±153 U/l) compared to both baseline (215±49 U/l, $p<0.01$) and the laparostoma group (264±153 U/l, $p<0.01$).

The clinical parameters also changed rapidly after the appearance of the acute abdominal problem, although in a different manner in both groups. In the zipper technique group, body temperature increased statistically significantly up to 40.3±0.22 ^{o}C compared to baseline (38.2 ± 0.2 ^{o}C, $p<0.001$), while the average values in the laparostoma group were similar to those taken prior to the operation (38.8 ± 0.1 ^{o}C, $p<0.001$). A similar dynamics was present in respiratory and heart rates: the former increased from 111.1+3.8 min^{-1} at baseline to 193.5±15.9 min^{-1} (zipper group, $p<0.01$) and 153.8 ± 9.2 min^{-1} (laparostoma, $p<0.05$) while the latter was initially 25.3 ± 1.4 min^{-1} and then accelerated up to 39.7 ± 3.8 min^{-1} (zipper group, $p<0.05$) and decreased to 23.0 ± 1.9 min^{-1} (laparostoma group, $p<0.05$ between groups).

The microbiological findings in the peritoneal exudate showed a presence of *E. coli* and *Proteus sp*.

DISCUSSION

The most characteristic electrocardiographic signs, established in the present study, were ST depression, depression and inversion of the T wave. These are typical changes accompanying hypokaliemia (Tomov, 1986). In our studies, there was no correlation between electrolyte disturbances and ECG findings, suggesting another cause for the changed heart's electrical activity. ST depression and T wave depression occur in tissue hypoxia too (Anonymous, 1990; Maclead et al., 2001; Marchev, 2002). They state that ST segment deviations did not appear in all leads (characteristic for hypokaliemia) and we confirmed that statement in our studies as

well. The myocardium is a tissue with exceptionally aerobic type of metabolism and hypoxia affects inevitably its electrical activity (Taylor et al., 1995, Li et al., 1998; Jacobsen et al., 2001; Hamminen et al., 2001). Evidences for the presence of tissue hypoxia are the high LDH activities in the zipper group and the increased values of venous pO_2, SAT and O_2CT, close to those in arterial blood. Most probably, the primary pathogenic factor in this case are biogenic amines, released from the putrefactive bacteria *E. coli* and *Proteus sp*., isolated from the site of infection. They provoke a considerable vasodilatation, hypovolemia and appearance of compensatory tachycardia, manifested by the shortened R-R interval. The increased body temperature and the leukocytosis (Dinev et al., 2000) conformed the bacterial contamination. The endotoxaemia results in changes in membrane systems of cells and thus, inhibits the mitochondrial function and the synthesis of macroergic phosphates (Webster, 1999). From the other part, the activation of phagocytosis results in increased blood concentrations of superoxide radicals that could directly damage myocardial mitochondria and thus, impair tissue respiration (Valdez and Boveris, 2001; Wickens, 2001). Therefore, severe peritonitis increases the metabolic rates and the systemic oxygen needs, but cells are not capable to utilize available oxygen (Leach and Treacher, 1998).

The opinion of Marchev (2002) is that repolarization changes (ST–T) could also be secondary, accompanying ventricular hypertrophies and bundle branch blocks. In such states however, the presence of preliminary depolarization disorders is essential (pathological R wave heights, QRS split, high Q orS waves amplitudes) that are opposed to repolarization changes. In our study, such electrocardiograms were not obtained. The decreased PQ interval, T wave or ST segment durations could be explained with the enhanced heart rate (Athwale et al., 1989) as result of the peritoneal irritation and vegetative sympathetic effects.The larger QRS complex illustrated the delayed conduction in the ventricular myocardium due to the lower diastole time (TP). The latter combined with increased systolic time (QT) suggests a mobilization of cardiac energy reserves under the influence of a powerful vegetative stimulus, intoxication and myocardial tissue hypoxia (Tomov, 1986; Ivanov et al., 1990; Kostov, 1995; Antzelevitch et al., 1998).

The semi-horizontal electrical position of the heart, persisting during experimental peritonitis in both groups was probably due to the high position of the diaphragm and the relative cardiac displacement in right recumbency and had no relation with any hypertorphy (Anonymous, 1990; Kostov, 1995).

CONCLUSIONS

In peritonitis, treated by the zipper technique, the electrical activity of the heart was probably impaired under the influence of bacterial toxins and vasoactive amines, absorbed in blood that provoked myocardial tissue hypoxia manifested with ST depression, depression and inversion of the T wave, shorter diastole and bigger systolic index.

In dogs with acute peritonitis and open abdomen, ECG changes were most likely due to vegetative sympathetic irritation and hypokaliemia resulting from the extensive fluid and electrolyte losses from the abdominal cavity. They were manifested by shortening of all intervals with exception of the QRS complex and by a smaller ST depression. The laparostoma technique for treatment of peritonitis pre-

served the myocardium from the toxic influence of bacterial products, accumulated in the abdomen.

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