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PREVALENCE OF FELINE CARDIOMYOPATHY PHENOTYPES AND ARTERIAL THROMBOEMBOLISM

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The aim*: To investigate the prevalence of cardiomyopathy (CMP) phenotypes and the weight of cardiogenic arterial thromboembolism (ATE) as a complication in cats. To determine the influence of age, breed and sex on the frequency of detection of CMP and ATE. Animals: One hundred and seventeen cats with various phenotypes of cardiomyopathies.*
Materials and methods*: the database of the veterinary center was analyzed. From 1066 studied cats, 117 stories of animal diseases were selected, in which the diagnosis of cardiomyopathy was established.*
Results*: In the experimental group, the prevalence of CMP was 11 % (HCMP - 94 %; DCMP - 3.4 %; RCMP - 2.6 %). Males were affected more often and had a more severe course. As the age of the animals increased, the relative frequency of heart failure increased slightly, but CMP was diagnosed more often in young animals. The Scottish Straight, Scottish Fold, European Shorthaired, European Longhaired, British Longhaired, and Canadian Sphynx can be considered susceptible breeds in Vinnytsia. There have been no cases of cardiomyopathy in Maine Coons. 57 % of cats with HCMP phenotype were asymptomatic. Arterial thromboembolism occurred in 14.5 % of animals with various CMP phenotypes. The lethality of ATE before discharge was 17.6 %, euthanized (different time period after the incident) 29 %.*
Conclusion*: HCMP phenotype is the most common. Probably, genetic factors related to sex and breed have a significant influence on the development of cardiomyopathy. More often, CMP phenotypes were diagnosed in younger animals. Heart failure develops more often in older animals. The number of animals with ATE and HCMP phenotype is high, but relative to the number of animals with heart failure, cats with DCMP were more prone. ATE occurred more often in females. Thromboembolism is more common in the European Longhair breed.*
Keywords: *asympthomatic cardiomyopathy, cardiac screening, congestial heart disease, echocardiography, hypertrophic cardiomyopathy, metropolis, Scottish Fold, transient cardiomyopathy*

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1. Introduction

Heart pathology in domestic cats occupies an important place in the practice of a veterinarian. Heart failure (HF) is one of the ten most common causes of death in cats [1]. The diagnosis of cardiomyopathy (CMP) is established more often [2].

In veterinary medicine, an adapted classification of myocardial pathologies is adopted, which is based on phenotypic features and often does not take into account the main cause. It focuses on a clinical rather than a genetic approach. There are hypertrophic (HCMP), restrictive (RCMP), dilated (DCMP), unclassified (UCMP) and arrhythmogenic (ACMP) cardiomyopathy [3]. HCMP phenotype is the most common [2].

Overall mortality in cats with HCMP is higher compared to clinically healthy cats. Echocardiography is the most reliable method of examining cats with HCMP [4]. Preclinical HCMP often leads to the development of heart failure, arterial thromboembolism, or sudden death of the animal [5].

Cardiogenic arterial thromboembolism is a frequent complication of heart failure in cats. Violation of filling of the left ventricle (LV) leads to the expansion of the left atrium (LA), decrease in its functioning and damage to the endothelium [6]. During an echocardiogram of cats with blood stasis in the LA, the operator can notice an increase in echogenicity in the cavity of this chamber, which is called "smoke" [7].

The prevalence of cardiomyopathies in the cat population was studied in at least 21 countries (USA, France, Great Britain, Germany, Sweden, Canada, Australia, and others) [2, 5]. In Ukrainian science, there is a tendency to increase interest in the issue of cardiomyopathies of cats [4, 8, 9], however, the authors did not find a single study of the prevalence of these pathologies in the conditions of the city of Vinnytsia.

Aim. The prevalence of cardiomyopathies in this region was not described in the available literature. However, the information is important, because the statistics are influenced by the gene pool and the indicators may differ significantly from the data, obtained in other countries or cities. The aim was to investigate the frequency of cardiomyopathies and their complications in cats in Vinnytsia; to find out whether age, breed and sex affect the severity of the course and the frequency of detection of CMP and ATE; to determine the perspective of further studies of the prevalence and course of CMP in cats in other regions.

2. Materials and methods

The database of the "VetHouse" veterinary center was analyzed for 616 days (from May 20, 2020 to January 26, 2022). During the selected period of time, 1066

cats of the city of Vinnytsia were examined. Groups of animals, for which echocardiography was recommended, and the results of which were analyzed in this article: cats before operations; cats that have reached 7 years of age; animals belonging to breeds of risk groups. In addition, cats with symptoms of certain diseases were examined and studied according to the referral of the attending physician (internal clinic or referral from other clinics in the city of Vinnytsia).

The study complies with the recommendations of ARRIVE and was conducted without violating the guidelines of the Directive 2010/63/EU on the protection of animals, used for scientific purposes [10, 11].

After the analysis, 117 case histories of cats were selected, in which diagnoses of HCMP, DCMP or RCMP were established after echocardiographic examination. Some had heart failure (HF) and/or ATE. During the studied period, no arrhythmogenic or unclassified cardiomyopathy was detected.

The animals had a complete medical history (owner data, anamnesis, clinical data of the patient and results of cardiological examination). Animals with heart failure and other complaints required a more detailed cardiac examination: a detailed anamnesis, additional clinical data and detailed echocardiography. The following groups of animals were formed, depending on the echocardiographic data:

HCMP phenotype. This group turned out to be numerous, diverse in echo-signs and symptoms, so it was fair to divide it into subgroups: suspicious for HCMP; HCMP phenotype; HCMP with heart failure and transient cardiomyopathy (TCMP).

The subgroup "suspicious for HCMP" consisted of animals that had a diastolic left ventricular wall thickness of 5.2 to 6 mm, in the absence of other echocardiographic abnormalities

Animals with symmetric or asymmetric LV wall hypertrophy (diastolic thickness greater than 6 mm [12]), papillary muscle hypertrophy [8] were included in the "HCMP phenotype". Diastolic dysfunction (change in IVRT, E/A and E'/A' ratio). Some animals had anterior systolic mitral valve motion (SAM), defined as a displacement of the anterior septal leaflet into the LV outflow tract, causing dynamic obstruction with accelerated blood flow and mitral regurgitation. LV systolic function is not reduced [13]. There were no other echocardiographic abnormalities.

Animals with HCMP and heart failure had echo-signs of LV hypertrophy (LV wall thickness in diastole greater than 6 mm, papillary muscle hypertrophy, diastolic dysfunction) and signs of left-sided congestive heart failure: LA size in the right parasternal approach in the 4-chamber projection greater than 14 mm, the ratio of LA to the aorta more than 1.7 in the short projection.

Animals, admitted with acute heart failure, in which the HCMP phenotype was detected during echocardiography, however, after several months of therapy, the condition of the animal and the echo-pattern normalized, were included in the "transient cardiomyopathy (TCMP)" group. Not all animals had troponin I levels measured, so this indicator was not included in the analysis.

The DCMP phenotype was determined in animals with reduced systolic function: Simpson ejection fraction less than 40 %, LV end-systolic size greater than 11 mm, LV end-diastolic size greater than 18 mm; and signs of congestive heart failure (LA size in the right parasternal approach in the 4-chamber projection more than 14 mm, the ratio of the LA to the aorta more than 1.7 in the short projection). The thickness of the LV walls could be normal or reduced [3].

The RCMP phenotype was established in animals with significant LA dilatation (ratio to the aorta greater than 2), diastolic dysfunction (restrictive type of LV filling), normal or slightly increased wall thickness (up to 6 mm) [14].

In the study, only phenotypic categories were analyzed without determining the cause of hypertrophy (hyperthyroidism, hypertension, etc.), because additional studies were not conducted in all animals, so the indicators may not be objective.

Statistical processing of information was carried out using a personal computer using the Microsoft Office Excel 2007 program. The relative values of the number of animals from each group (subgroup) are expressed as percentages (%) and were calculated relative to the total number of animals with cardiomyopathy phenotypes. Normality of continuous data was assessed graphically. For the convenience of analyzing animals by age, an interval variation series was formed. Age values for phenotype groups consisting of 6 or more animals were reported as median and range. All options were listed in smaller groups. A mode was also specified for some groups. The nature of the relationship between age and the frequency of detection of the phenotype of cardiomyopathies and heart failure was evaluated using the pairwise correlation coefficient. It was calculated in the form of a linear correlation coefficient (Pearson) by comparing two series - age and: number of animals with pathology; the absolute number of HF cases; of the relative number of HFs (correlated to the number of detected CMPs).

3. Research results

For 616 days, 1066 cats were examined in the veterinary center. After the analysis, 117 animal disease histories (11 %) were selected, in which one of the phenotypes of cardiomyopathies (CMP) was established.

The diagnosis was established more often in males – 66 %, in females – 34 % (Fig. 1). Cardiomyopathies in males had a more severe course and more often caused heart failure. Thus, heart failure in female cats with the CMP phenotype was registered in 40 %, whereas in male cats this indicator reached 50 %. Male cats with HF have a higher mortality during the crisis, compared to female ones: in the first days, 12.8 % of males and 6.6 % of females died (relative to the number of animals with HF). Such a complication as ATE in our study occurred with a similar frequency in both sexes – females 46.6 %, males 41 % (relative to the number of animals with HF).

The distribution of animals by age was not normal. The median age at diagnosis was 5.8 years, with a range from 3 months to 20 years (average age of females was 7.7 years, males 5.7). For ease of analysis, the animals were divided into age groups: up to one year, from

1 to 5 years, from 5 to 10 years, from 10 to 15 years, and over 15 years (Fig. 2).

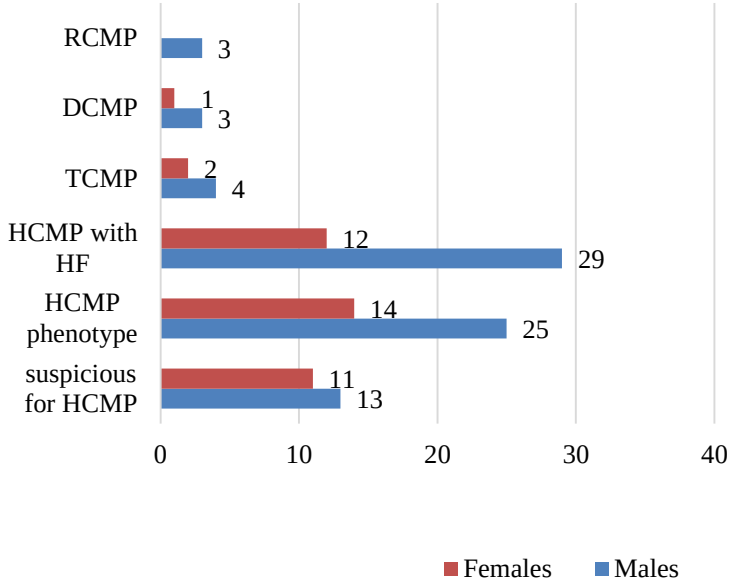

Fig. 1. Distribution of groups of animals with CMP by sex

Most of the animals belonged to the age of 8 years (68.4 %). A negative correlation (r=–0.8) of the frequency of detection of the CMP phenotype with age was observed, i.e., the diagnosis was more often established in younger and middle-aged animals (up to 8 years). There is also a negative correlation of the absolute number of HF cases with age (r=–0.75), however, the relative number (percentage of the development of heart failure from the total number of diagnosed HF) slightly increased in older animals (r=0.2).

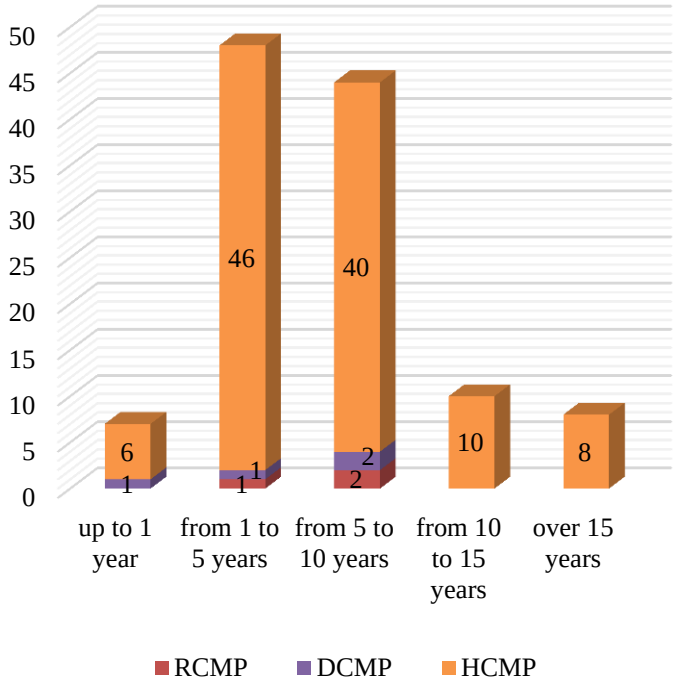

Fig. 2 Age groups of animals with CMP

Cat breeds that more often had the CMP phenotype were Scottish Straight, Scottish Fold, European Shorthair, European Longhair, British Longhair, and Canadian Sphynx. It is less often diagnosed in Bengal, British Shorthair breeds and half-breeds. Other cases can be considered isolated (Fig. 3).

It was noticed, that the severity of heart pathology is not the same in different breeds (Fig. 4). Scot-

tish Fold and Scottish Straight more often had the HCMP phenotype, however, heart failure occurred in the former only in 33 % of cases. In Fold, the percentage of HF is higher (44 %), however, this figure is increased by a significant percentage of TCMP, which passed in a few months. If we take into account the animals of this breed without taking into account TCMP, then HF was found in 34.8 %. In the European Shorthair, the frequency of development of HF is not high - 34 %, although the CMP phenotype was detected in a significant number of animals of this breed. Half-breeds in our study were not often affected and had HF in 40 % of cases. Among these animals, no ATEs or deaths were recorded during the crisis.

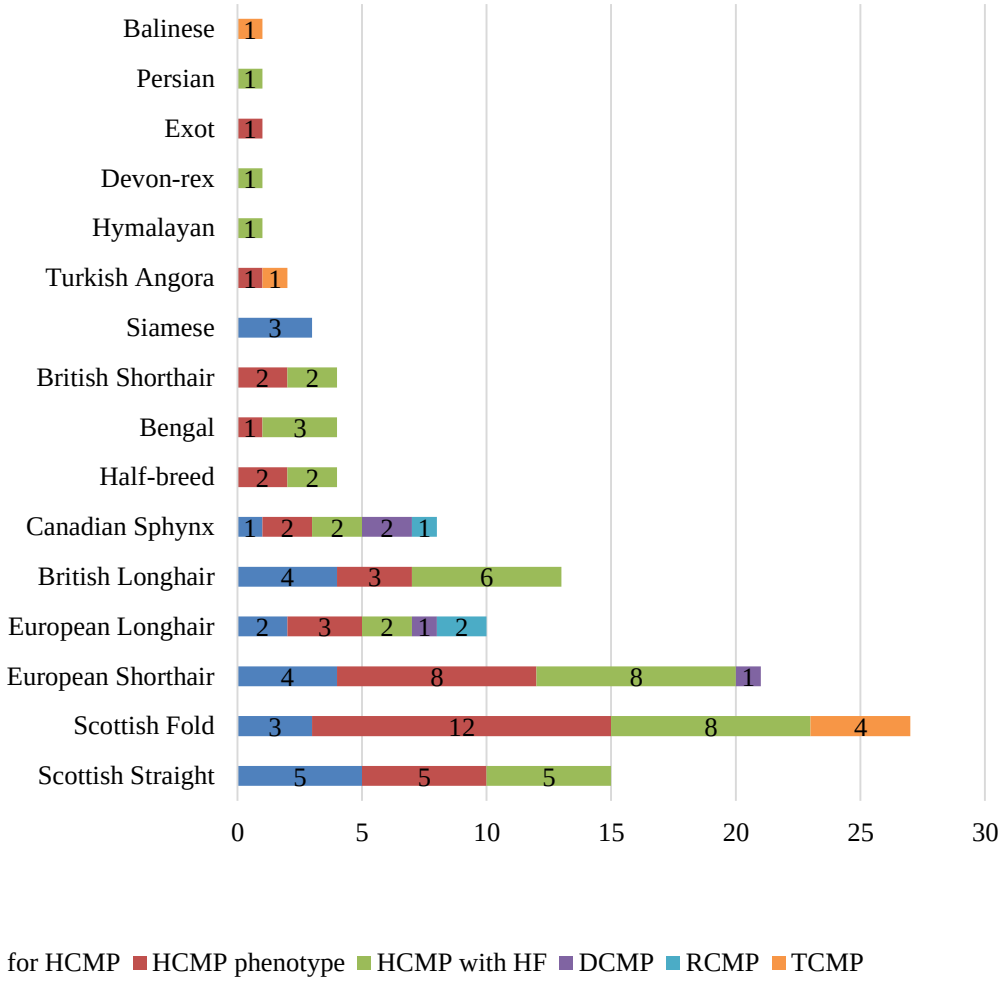

Fig. 3. Breeds of cats, in which cardiomyopathies of various phenotypes were detected

Highland Straight, European Longhair and British Shorthair are the next most difficult in clinical course. In them, HF developed in about 50 % of cases. Sphynx (62 %) and Bengal (75 %) cats had the most severe course of CMP with the development of HF, however, their mortality during the crisis was zero.

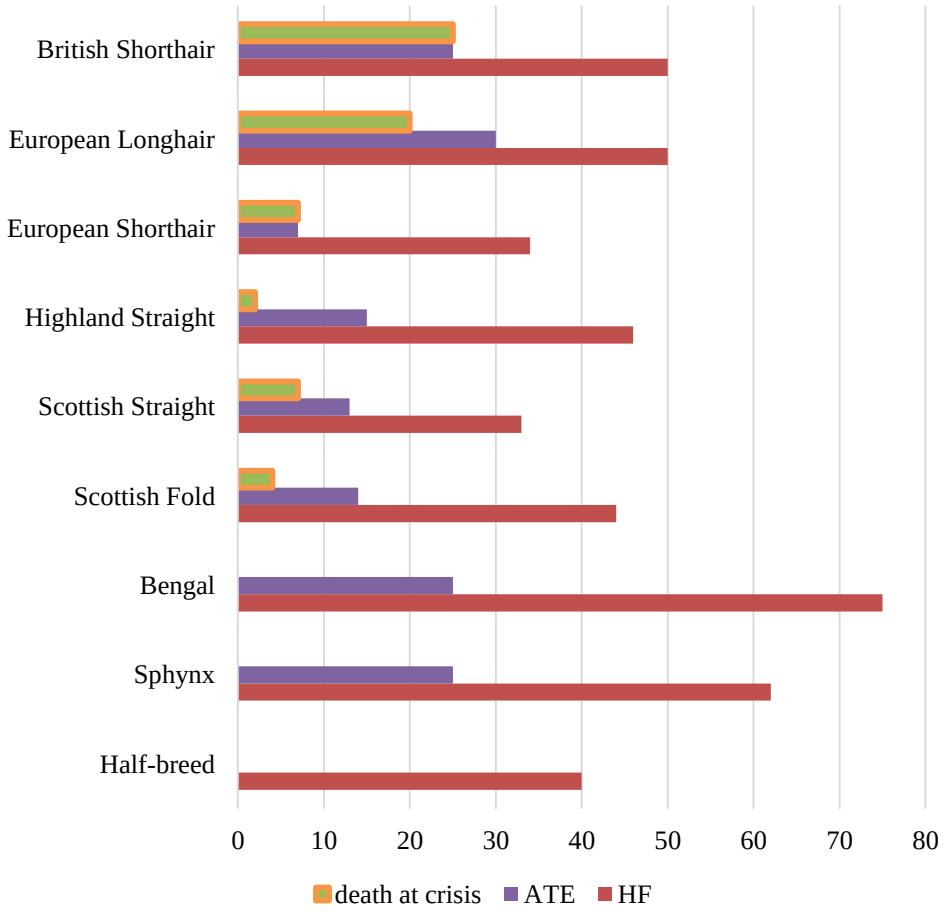

Fig. 4. Severity of the course of CMP by cat breeds (expressed as a percentage of the total number of animals of this breed in the group)

The phenotype of hypertrophic cardiomyopathy (HCMP) was detected in 110 (94 %) patients. Such a diagnosis was established in animals that had an increased thickness of the interventricular septum, the back wall of the left ventricle, and/or the papillary muscles. The median age was 6.37 years (3 months to 20 years). Young animals and middle-aged cats were more often affected. The age distribution of animals up to 8 years old was normal and 70 % of animals belonged to this age range (Fig. 5).

The group of animals with HCMP turned out to be large and diverse in terms of echo-signs and symptoms, so it was correct to divide it into subgroups. "HCMP Suspects" (n=24, 20.5 %) had a median age of 5.1 years (7 months – 19 years), 50 % were between 3 and 6 years of age. All representatives of the Siamese breed belong to this group, 21 % of cats belong to the Scottish Fold breed (Fig. 3). "HCMP phenotype" (n=39, 33 %) was 3.6 % of the total number of examined animals, the median age in the group was 6 years (6 months – 17 years). 59 % of the animals were between 2 and 7 years old, the mode in this range was 2 years. The "HCMP with heart failure" subgroup included 41 animals (35 %). The median age in the subgroup was 7 years (3 months – 20 years), the mode was 2 years, 65.8 % of cats were under 8 years of age. HF was detected with a similar frequency among animals of both younger and middle age. Most of the representatives of the Bengal breed (75 %) belonged to this subgroup. Breeds that were in the majority: European Shorthair, Scottish Shorthair.

Patients of this subgroup came to the clinic for veterinary care with symptoms of congestive heart failure (CHF). 14 animals were admitted with arterial thromboembolism (ATE), representing 34 % of this subgroup. This complication significantly affects the course (appearance of pulmonary edema; effusion in the chest and pericardial cavities) and prognosis – animals more often died or were euthanized during the crisis (Table 1).

From the subgroup of animals that had HCMP with heart failure, 14.6 % of cats died in the first 5 days, 9.7 % died within 2 months (from 19 to 60 days). 12 % of animals were euthanized during the crisis (more often due to ATE).

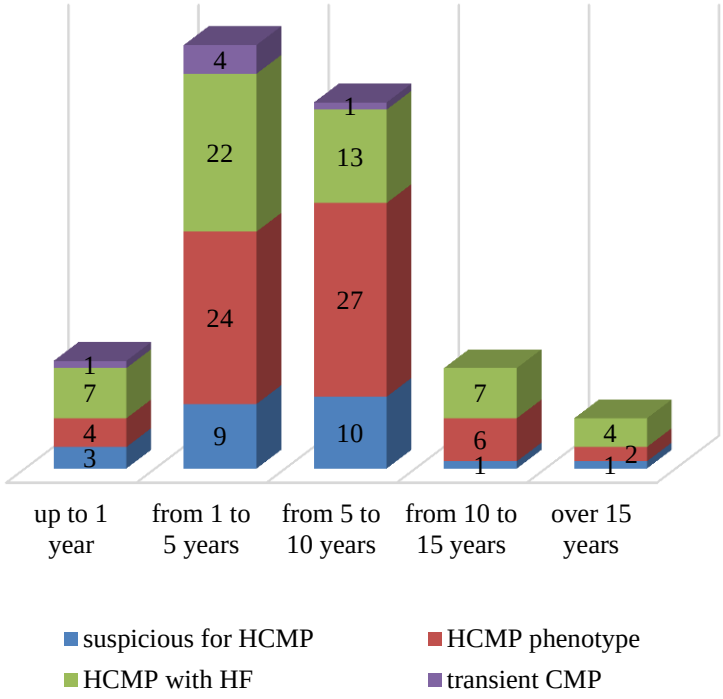

Fig. 5. Distribution of animals with HCMP by age groups

Table 1

Comparison of the severity of the course of HCMP between animals with CHF and those who had CHF and ATE

Condition of chest organs	Cats with ATE			Cats without ATE		
	Number of patients	Died at crisis	Euthanized at crisis	Number of patients	Died at crisis	Euthanized at crisis
Without signs of pulmonary edema or effusion in the cavities	4	2	2	13	0	0
With pulmonary edema	6	0	2	8	1	0
With effusion in the chest and/or pericardial cavity	3	1	0	3	1	0
With effusion in the chest and/or pericardial cavity and pulmonary edema	1	0	0	3	1	1

The subgroup of animals with *transient cardiomyopathy (TCMP)* included 6 cats. Of them, 4 belonged to the breed of the Scottish Highlander. These animals were admitted to the veterinary center with signs of acute heart failure (HF). They were distinguished by a younger age in the range from 1 to 5.8, the median was 2.8 years. Some of the patients were examined a few days or weeks before the occurrence of HF, and echosigns of pathology were not detected. Cats had a history of anesthesia, transportation, or other stressful events. The patients' general condition and echocardiographic parameters normalized during the prescribed therapy.

Animals with the phenotype of dilated cardiomyopathy accounted for 3.4 % (n=4) of the number of animals with CMP. One cat, 4 months of age, had cardiomyopathy secondary to malnutrition and fully recovered with the prescribed therapy and diet. The rest of the animals were 3, 8 and 10 years old.

Half of the cats (50 %) belonged to the Canadian Sphynx breed.

3 animals came to the veterinary center with pulmonary edema, and 1 animal with exudative pleurisy. 2 cats had arterial thromboembolism - both died (one during the crisis, the other 15 days later). The remaining animals were given therapy and at the time of data collection for analysis, their death was not known.

Three males aged 4, 8 and 9 years were included in *the group of cats with RCMP*. Two animals (66 %) belonged to the European Longhair breed. One cat came to the clinic with arterial thromboembolism. One animal each had pulmonary edema, pleural fluid, and simultaneous edema with sweating. The last, the only one from the group died on the 38th day after the crisis (at the time of data collection).

Arterial thromboembolism, as a common complication of cardiomyopathies, occurred in 17 cats (14.5 %). Animals with HCMP phenotype were affected more often, however, cats with DCMP in our study were more susceptible (if we take into account the number of cats with ATE relative to animals with HF with this phenotype). The European Longhaired turned out to be more susceptible (relative to the number of animals with CMP) (Fig. 4).

From the group of animals with ATE, a decision was made to euthanize 29 % (4 cats, 1 of them before discharge). 14 cats (82 %) survived to discharge. 2 animals died during the crisis, 3 died within 2 months (19–60 days) (43 days on average).

4. Discussion of research results

In the available literature, studies of the prevalence of pathology among clinically healthy cats were found, however, studies that included symptomatic animals were not found. Therefore, the advantage of the study is the reflection of the prevalence of pathology close to daily practice. We managed to find the prevalence of cardiomyopathies and heart failure also among younger animals, although it was previously believed, that older animals are more prone to these pathologies. In the study, it was possible to disprove the idea that some breeds are prone to CMP. This is probably related to the composition of the gene pool that is widespread in the studied region. Such results may lead to a transformation of the understanding of the development of cardiomyopathies and the creation of new recommendations for planned screening studies.

The disadvantage is that the work analyzes exclusively phenotypic categories without a full-fledged additional examination and long-term observation of animals with myocardial pathologies.

In the examined males, cardiomyopathy was more often diagnosed and this coincides with the results of many studies. Thus, the analysis of insurance cases among cats in Japan showed that males are more prone to cardiovascular pathologies [1]. According to other studies of the prevalence of cardiomyopathy, male sex is indicated as one of the factors, associated with the development of HCMP [2].

We did not find a high prevalence of heart pathologies in Persian and Bengal cats (1 and 4 cases, respectively). Not a single case of cardiomyopathy was recorded in the Maine Coon breed, despite the fact that there are kennels in the city of Vinnytsia, from which animals are regularly examined before breeding or sale. No such pathologies were recorded among breeds, such as Norwegian Forest, Ragdoll and American Shorthair. According to the literature, most cats with HCMP are not purebred animals, however, it is believed, that the pathology is more common among some breeds. In various studies, the following breeds were called prone: Domestic Shorthair, Maine Coon, Persian, Domestic Longhair, Norwegian Forest, Sphynx, Chartreuse [15], Bengal [12], Scottish Fold, American Shorthair, Ragdoll [1]. We got different results. This may be due to the small number of representatives of some breeds in the studied region.

The HCMP phenotype was recorded more often in animals under 8 years of age and its prevalence is lower than that reported in Great Britain, where it was 14.7 % among asymptomatic animals. This publication also showed that older animals were more affected by HCMP. However, it is impossible to fully compare the results, because there are differences in the selection criteria [2]. HCMP occupies an important place among pathologies in cats. A retrospective study showed that within 2 years after the diagnosis of HCMP, 9 % died from ATE, 17.3 % from congestive heart failure, and 4.7 % died suddenly [16]. And a postmortem study of animals found that heart disease, especially HCMP, was often present in cats that died suddenly [17].

Dilatation of the left atrium is considered an important criterion for the presence of left-sided heart failure, which can warn of future clinical complications in all forms of cardiomyopathies [6]. More often, such animals are registered during admission due to pulmonary edema. Some come with arterial thromboembolism and after diagnosis it turns out that the animal has had heart failure for a long time. This group also includes cats without symptoms, in which HF is still compensated.

Animals under 8 years of age with HCMP can be considered more prone to the development of HF. Similar results were obtained in a study by scientists from the city of Dnipro, where 14 out of 17 animals with HCMP were under 6 years of age, but middle-aged animals (4–6 years) were more often affected [9]. According to the results of our study, younger cats were as prone to the development of HF as middle-aged animals, in contrast to the results of the already mentioned study [9].

Animals with transient cardiomyopathy were distinguished by a younger age, which confirms the results of a study comparing animals with TCMP and HCMP [18]. Animals with secondary cardiomyopathies have a better prognosis [19], because it is often possible to influence the primary cause.

Today, researchers believe that the prevalence of DCMP is up to 5 % of the number of animals with CMP [14], which completely coincides with our results. One in four animals had alimentary dilated cardiomyopathy, although taurine deficiency was the most common cause until 1987. The etiology of DCMP in most animals remains undetermined [14].

Restrictive cardiomyopathy is characterized by isolated LV diastolic dysfunction due to endocardial,

subendocardial or myocardial fibrosis. This is an understudied myocardial disease in cats, often with an unclear etiology [14].

The results we obtained turned out to be similar to a miniature, which in some details resembles a large-scale 10-year study by Japanese scientists [20]. In the aforementioned research, 41 cases of restrictive cardiomyopathy were studied. From similar patterns we have age (median 6 years), males were more often affected (61 %), most were Domestic Shorthairs. Of course, our 3 cases are not able to reflect the characteristic features of the pathology, because our study had a different goal. We can also conclude that RCMP is diagnosed much less often in the conditions of the city of Vinnytsia.

Cardiogenic arterial thromboembolism is a common complication of cardiomyopathies. No analysis of breed predisposition to this pathology, which was highlighted earlier, was found. The percentage of euthanasias in the study turned out to be lower than that published in 2013 in Great Britain, where only 27.2 % of cats lived for more than a day [21]. This may be related to the transformation of attitudes towards the pathology.

The lack of long-term survival analysis and data on sudden death was a limitation of the study.

It was possible to identify the prevalence of CMP, the influence of age and susceptible breeds, different from previous studies. Further studies of the prevalence of cardiomyopathies in other regions may indicate new features of the course and reveal new trends in the development of the pathology, so they have a perspective.

4. Conclusions

So, according to the set tasks, we determined:

Cardiomyopathies were established in 11 % of animals (HCMP – 94 %; DCMP – 3.4 %; RCMP – 2.6 %). The most common phenotype is HCMP (complications: HF – 42.7 %, ATE – 12.7 %, death in the first days – 14.6 %), however, most animals were asymptomatic. DCMP and RCMP phenotypes were not often diagnosed in the conditions of the city of Vinnytsia and were always associated with the development of HF.

CMP was diagnosed more often in younger animals. With age, the relative frequency of HF increased slightly.

Predisposed breeds of cats can be considered Scottish Straight, Scottish Fold, European Shorthaired, European Longhaired, British Longhaired, Canadian Sphynx. The European Longhair turned out to be more prone to ATE. TCMP was more often registered in the Scottish Fold breed.

ATE occurred more often in animals with HCMP phenotype, although cats with DCMP in our study were more prone (50 % had thromboembolism). In our research, the percentage of euthanasia in animals with ATE is minimal. 82 % of cats survived to discharge.

Significant differences from previous studies were a decrease in the prevalence and age of pathology registration (often occurred in young animals), refutation of the prevalence of cardiomyopathy among some breeds (probably regional in nature). Further studies of the prevalence and factors influencing the development of cardiomyopathies in cats in other regions can be considered promising; study of complications of cardiomyopathies and prevention of their occurrence.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this study, including financial, personal, authorship, or any other, that could affect the study and its results, presented in this article.

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