Chapter 13

PREVALENCE AND CLINICAL SIGN OF MYOCARDIAL DYSTROPHY IN HIGH-YIELD COWS

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INTRODUCTION

Animal husbandry is one of the main branches of agriculture in Ukraine. In recent years, there has been a tendency to improve the genetic potential of dairy cows. High-yielding cows are quite picky about the conditions of keeping and feeding[1,2], which, unfortunately, are often violated, which, in turn, leads to the development of such pathologies in animals as ketosis, liver diseases, acidosis and alkalosis of the rumen, ruminitis, displacement of rennet, postpartum hypocalcemia, secondary osteodystrophy, hypovitaminosis and other diseases[3]. About 10% of pathologies in these animals are related to heart diseases.

Diseases of the cardiovascular system in farm animals actually occur more often than are diagnosed by specialists and registered in veterinary documentation. They quite often occur as a complication of infectious, invasive, as well as many non-infectious diseases. Animals often die after the elimination of the main disease as a result of irreversible changes of a toxic nature that occur in the heart and blood vessels[4].

Damage to the heart more often occurs as a secondary complication of diseases caused by metabolic disorders, gynecological, surgical, infectious and parasitic diseases, acute or chronic intoxication of the body. Their emergence is facilitated by stress factors – hypokinesia, crowding of animals, noises of activated mechanisms[5]

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[2] Кравцов Е., Кукла Л. Молока і м'яса можна виробляти більше… *Тваринництво України*. 2006. № 5. С. 5–8.

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[4] Paccioli D. Clean cows / *Research / Penn State*, 2018. Vol. 19. № 1. P. 23–29.

[5] Spirito P., Bellone P. The natural history of hypertrophic cardiomyopathy. *British Heart Journal*. 2014, № 72. 10 p.

Myocardiodystrophy occupies a special place among various non-inflammatory lesions of the heart. It has been proven that the disease can occur as a result of various diseases, including those not directly related to damage to the circulatory system[6].

1. Clinical and functional state of the cardiovascular system in clinically healthy high-yield cows

In the practice of veterinary medicine, the cardiovascular system is examined in a certain sequence, starting with examination and palpation of the chest in the heart area. Then, percussion of the heart area is performed to determine its percussion boundaries and to detect pathological conditions of the pericardium and myocardium. The main method of heart examination is auscultation. If necessary, additional (special) methods are used: electrocardiography, phonocardiography, sphygmography and phlebography, arterio- and phlebotonometry (blood pressure measurement), determination of blood circulation rate, X-ray and ultrasound examination[7].

The use of general clinical and special research methods (ECG, ACT measurement) makes it possible to objectively assess the functional state of the heart in farm animals.

Studies of 116 clinically healthy deep-bodied and dairy cows did not reveal edema in the area of the underarm and limbs. Palpation of the heart area revealed that the heartbeat was localized, moderate, not painful, and rhythmic. Auscultation of the heart was found to be clean, clear, appropriate in timbre for healthy animals, without changes in tones.

Determination of the heart rate (HR) is an important diagnostic test, since its changes, in particular tachycardia, are one of the clinical signs of heart failure[8]. We found that in 48 healthy high-yielding deep-bodied cows, the heart rate averaged 71±0,83 beats/min (58–78), in 26 newly calved cows – 72±0,7 (64–76), and in 42 clinically healthy dairy cows – 72±0,74 beats/min (60–80) (Table 1). That is, in clinically healthy cows, regardless of their physiological condition, the pulse rate was within the normative values, since 96,3–98,4 % of the values were in the range of M±2δ.

Since the pulse rate of cows in different technological groups does not differ significantly, we summarized the results of the study for all 116 cows.

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[6] Morphology of the atrioventricular valves and related Intraventricular structures in the wild pig (Sus scrofa) / Ates S, Karakurum E, Takci L, et al. *Folia Morphol*. 2017. 7(4). P. 650–679.

[7] Characterization of MB creatine kinase isoform conversion in vitro and in vivo in dogs / J. J. Billadello, H. L. Fontanet, A. W. Strauss and D. R. Abendschein. *J. Clin. Invest*. 1989. № 83 (5). P. 1637–1643.

[8] The development of fatal myocarditis and polymyositis in mice heterozygous for IFN-α and lacking the SOCS-1 gene / Donald Metcalf, Ladina Di Rago, Sandra Mifsud et al. *Proc. Natl. Acad. Sci.* U S A., 2000. № 97(16). P. 9174–9179.

According to these indicators, the pulse rate ranges from 58 to 80 beats per 1 min. Given the value of the standard deviation (δ = ±4), it can be stated that in 78,5% of cows the pulse rate is in the range of 68–76 beats per minute (M±δ), and in 96,2% – 64–80 beats per minute (M±2 δ).

Table 1

Pulse rate in clinically healthy high-yield cows

Indicators	Heart rate, bpm		
	Deep-pregnant cows (n=48)	Newly calved cows (n=26)	Early lactation cows (n=42)
Lim	58–78	64–76	60–80
M±m	71±0,83	72±0,7	72±0,74
δ	5	4	4
M±δ	66–76	68–76	68–76
M±2δ	61–81	64–80	64–80
p<	-	0,1	0,1

Note: p < – compared to deep-pregnant cows

The lungs are closely related to the heart both topographically and functionally. In deep-calving cows, the respiratory rate per 1 min was in the range from 16 to 28 (22±0,49), in newly calving cows – 14–28 (22±0,7), and in cows of early lactation, respectively, 16–30 (23±0,54) respiratory movements/min (Table 2).

Taking into account the value of the standard deviation (δ = ±4), the respiratory rate in clinically healthy high-yielding cows of different physiological groups is in the range of 18–26 respiratory movements /min (M±δ), which account for 81,9 % of all values, while in the range of 14–30 respiratory movements /min (M± 2δ) – 100 %.

The calculation of the mean square deviation (±2δ) showed that the respiratory rate in high-yielding heifers and dairy cows ranges from 14 to 30, which is slightly higher than according to the literature [210]. This is due to increased cardiac activity after transferring animals to tethered housing before calving (deep-calf cows) and high milk production, which requires an increase in oxygen supply to the organs.

Table 2

Respiratory rate in clinically healthy high-yield cows

Indicators	Respiratory rate, respiratory movements/min		
	Deep-pregnant cows (n=48)	Newly calved cows (n=26)	Early lactation cows (n=42)
Lim	16–28	14–28	16–30
M±m	22±0,49	22±0,7	23±0,54
δ	3	4	4
M±δ	19–25	18–26	19–27
M±2δ	16–28	14–30	15–31
p<	-	0,1	0,1

Note: p < – compared to deep-pregnant cows

Adaptation of the heart to a significant workload in the course of animal operation is one of the problems of modern dairy farming. An important component of cows' adaptation is a prolonged increase in the intensity of the heart. Therefore, the study of the functional state of the myocardium is important for the early diagnosis and prevention of heart disease[9][10]. In veterinary medicine, among the various methods for assessing the functioning of the heart of animals, the measurement of arterial blood pressure is important[11].

We found that blood pressure in clinically healthy deep-pregnant cows was within the following limits: systolic blood pressure (SBP) – 110,0–130,0; diastolic blood pressure (DBP) – 30,0–60,0 and pulse pressure (PP) – 60,0–90,0 mm Hg, among newly calved cows, respectively, SBP – 110,0–130,0 mm Hg; DBP – 40,0–60,0; PAP – 50,0–80,0 mm Hg (Table 3).

In cows of early lactation, blood pressure values were: systolic – 119,0±1,94 (100,0–140,0); diastolic – 46,0±1,29 (30,0–60,0) and pulse – 73,0±2,37 (50,0–95,0) mm Hg (Table 3).

Since the difference between the groups of animals is not significant (p<0,1), by calculating the standard deviation of SBP, MAP (δ=±10,0) and

[9] Висоцький А. О. Вплив умов утримання на функціональний стан серцево-судинної системи і гемопоез у корів в господарствах зони радіоекологічного контролю : автореф. дис. … канд. вет. наук. Львів, 2000. 21 с.

[10] Маркова О. О. Міокардіодистрофія і реактивність організму. Тернопіль : УКРМЕДКНИГА, 1998. 150 с.

[11] Внутрішні хвороби тварин / за ред. В. І. Левченка. Біла Церква, 2012. Ч. 1. 528 с.

DBP (δ=±7), we found that the physiological limits of ACP in 55 highly productive cows are within the following limits (M±δ) systolic – 110,0–130,0 mm Hg; diastolic – 39,0–53,0 mm Hg; pulse – 63,0–83,0 mm Hg, with 98,2 %, 90,9 % and 83,6 % of cows within these limits. If we take into account M±2δ, then SBP indicators have limits of 100,0– 140,0 mm Hg, within which 100 % of the values of all technological groups fall; DBP – 32,0–60,0 mm Hg – 98,2 %; PAP – 53,0–93,0 mm Hg – 96,4 % of all values.

Fluctuations in arterial pressure in highly productive cows are caused by increased blood circulation in the mammary gland, as about 500 liters of blood pass through it to produce 1 liter of milk[12].

The next method of studying the functional state of the heart is electrocardiography, which determines its disorders before the onset of clinical symptoms. In choosing the leads for ECG recording, we took into account the topographic features of the animal heart[13]. For cattle, sagittal and frontal leads proved to be the best[14]. ECG recording was performed in 22 cows of different technological groups.

During the study of healthy cows (deep-calving and newly calving) in which ECG was recorded, the heart rate was 71,0±1,19 (68–74) beats/min.

The ECG analysis shows that the cardiac cycle in cows is rhythmic, since the maximum fluctuations in the duration of individual cycles (R-R) did not exceed 10% and were within ± 6,4%. The rhythm is sinus, the alternation of the teeth is sequential. In the first lead, the electrocardiogram is characterized by a positive P wave in 87,5 %, a ventricular complex of the QRS type and a negative T wave in 75 % of animals (Fig. 1).

The P-wave, consisting of an ascending knee with a small protrusion, a rounded apex, and a descending knee, appears with the onset of atrial excitation and reflects the process of its onset and passage. In cattle, this tooth is well defined, positive, and often biphasic. Its average value in the group of animals was 0,1±0,004 mV (0,08–0,12; Fig. 2).

The Q wave is the initial part of the ventricular complex of the electrocardiogram. It corresponds to the period of excitation of the right papillary muscle, interventricular septum, apex of the right and left ventricles, and base of the right ventricle[15]. We found that in clinically healthy cows, the Q wave is weakly expressed with an amplitude of 0,013±0,005 mV (0,0–0,038).

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[15] Morphology of the atrioventricular valves and related Intraventricular structures in the wild pig (Sus scrofa) / Ates S, Karakurum E, Takci L, et al. *Folia Morphol*., 2017. 7(4). P. 650–679.

Table 3

ACP indices in clinically healthy high-yielding cows

Indicators			Deep-pregnant cows	Newly calved cows	Early lactation cows
Arterial blood pressure, mm Hg	systolic (SBP)	Lim	110,0–130,0	110,0–130,0	110,0–140,0
		M±m	121,0±1,67	120,0±2,13	119,0±1,94
		δ	11	10	9
		M±δ	110,0–132,0	110,0–130,0	109,0–129,0
		M±2δ	99,0–143,0	100,0–140,0	99,0–139,0
		p<	–	0,1	0,1
	diastolic (DBP)	Lim	30,0–60,0	40,0–60,0	40,0–60,0
		M±m	46,0±1,55	47,0±1,88	46,0±1,29
		δ	7	7	6
		M±δ	39,0–53,0	40,0–54,0	40,0–52,0
		M±2δ	32,0–60,0	33,0–61,0	34,0–58,0
		p<	–	0,1	0,1
	pulse (PAP)	Lim	60,0–90,0	50,0–80,0	50,0–90,0
		M±m	74,0±1,55	73,0±2,77	73,0±2,37
		δ	9	10	11
		M±δ	65,0–83,0	63,0–83,0	62,0–84,0
		M±2δ	53,0–92,0	53,0–93,0	51,0–95,0
		p<	–	0,1	0,1

Note: p < – compared to deep-pregnant cows

The most pronounced element in this lead is the R tooth, which consists of ascending and descending knees that form a sharp apex. The R wave indicates a gradual excitation of the ventricular myocardium. Its value averaged 0,27±0,047 mV with fluctuations from 0.14 to 0.4 mV (Fig. 2).

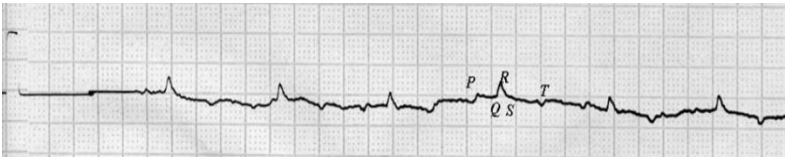

Fig. 1. Electrocardiogram of a clinically healthy high-yielding cow in the first lead

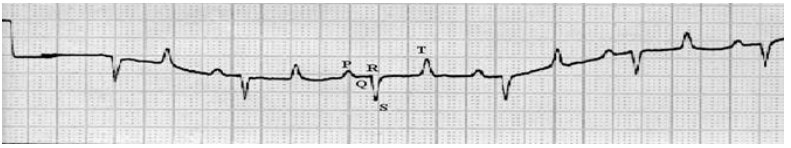

Fig. 2. Electrocardiogram of clinically healthy cows in the second lead

The S wave on the ECG is weakly expressed, directed downward from the isoelectric line and represents the terminal part of the ventricular complex, the descending knee of which is a continuation of the R wave[16]. Its amplitude is 0,03±0,004 mV (0,013–0,4) (Fig. 3.2).

The T wave is the terminal part of the ventricular complex. In cows, the T wave is characterized by a relatively large amplitude and may be negative in the first and third leads. The value of the T wave in clinically healthy cows was 0,14±0,022 mV with limits from 0,08 to 0,2 mV (Fig. 2).

In the second lead, the ECG of clinically healthy cows is characterized by a positive P wave, ventricular QRS complex and T wave (Fig. 2). The amplitude of the P wave is 0,12–0,26 mV (0,19±0,023). The negative orientation of the Q wave is weakly expressed and its voltage is 0,0–0,03 mV (0,019±0,005). The R wave has a value of 0,07–0,48 mV (0,27±0,073). The negative tooth S is the largest – 0,31–0.93 mV (0,62±0,11). The T wave is positive in all animals and its amplitude is 0.06-0.82 mV (0,44±0,068).

In the third lead, the electrocardiogram is characterized by a positive P wave, ventricular complex, mainly of the QRS type (Fig. 3). The amplitude of the P wave averaged 0,13±0,014 mV (0,07–0,21). The negative Q wave is expressed in 75 % of animals and has a value of 0,055±0,009 mV (0,0–0,095), the amplitude of the R wave is on average 0,18±0,048 mV (0,03–0,3). The most pronounced element of the ventricular complex of the third frontal lead is the S wave, whose value is 0,75±0,149 mV (0,33–1,17). The T-wave has an amplitude of 0,4±0,07 mV (0,2–0,6) and is electro-positive in 87,5% of animals (see Fig. 3).

[16] Clinical Use of Electrocardiogram. Ed. By Umashankar Lakshmanadoss. Intechopen. 2023. 960 p.

Fig. 3. Electrocardiogram of a clinically healthy cow in the third lead

An increase in the R wave voltages was found in 62,5 %, S – in 37,5 %, the T wave voltages were decreased in 25 % and increased in 62,5 % of animals. This is due to the system of keeping cows in our farms (tethered), as well as physiological characteristics, since ECG recording in all three leads was performed mainly on pregnant cows (60%). Thus, in dry animals in the last 3 months of pregnancy, sinus tachycardia, split teeth, and shifted intervals are observed. In cows of the first lactation, such changes are associated with the establishment of lactation function[17].

When analyzing the ECG, it is important to take into account not only the voltage of the teeth and their direction, but also the duration of the teeth and intervals, the results of calculations of individual indicators of the duration of the cardiac cycle (Tables 3 and 4).

The duration of the cardiac cycle in pregnant and dairy cows was practically the same (Table 4), and the difference between pregnant and dairy animals was 6,4 %. However, in dairy cows there is a tendency to decrease the duration of the diastolic period of the ECG (0,35±0,04 s), compared to dry cows (0,41±0,03 s), due to the opposite trend in the systolic period. The duration of atrial excitation is the same (0,08±0,01 s), and its share in the cardiac cycle of dry cows is 9, dairy cows – 9,3 %.

Absolute atrioventricular conduction (PQ) in cows of both groups is the same (0,17±0,01 s), and relative (AP=(PQ:RR)-100 %): in pregnant cows it is 19,1±0,85 %, in dairy cows – 19,8±1,35 %.

[17] Kostov Y. Electrocardiografic-telemetric and morphological studies on cardiac disturbances in cows under conditions of technological stress *Bulg. J. Agr. Sc.,* 1995. Vol. 1, № 3. P. 295–302.

Table 4

ECG waveform width in clinically healthy high-yield cows

Indicators		Tooth width, s		
		P	QRS	T
Deep-bottomed animals	Lim	0,06–0,1	0,04–0,09	0,09–0,15
	M±m	0,08±0,01	0,06±0,01	0,12±0,01
Cows of the dairy herd	Lim	0,06–0,12	0,04–0,11	0,08–0,12
	M±m	0,08±0,01	0,06±0,01	0,11±0,01
p<		–	–	0,1

Note: p< – compared to pregnant cows

The duration of the ventricular QRST cycle in dairy cows tends to increase (0,34±0,02 s) compared to deep-calving cows (0,31±0,02 s), with the same duration of the QRS complex (0,06±0,01 s) and almost the same width of the T wave. Thus, the tendency to increase the duration of the ventricular QRST cycle in dairy cows is observed due to an increase in the duration of the period between the S and T waves (ST), that is, the period when the myocardium is in the stage of complete depolarization, and this period lasts 0,17±0,01 s in them, compared to 0,13±0,01 s in pregnant cows ($p<0,01$).

Table 5

Duration of ECG intervals in clinically healthy high-yield cows

Indicators		Duration of intervals, s			
		P-Q	Q-T	T-P	R-R
Deep-bottomed animals	Lim	0,12–0,19	0,25–0,41	0,27–0,51	0,79–1,19
	M±m	0,17±0,01	0,31±0,02	0,41±0,03	0,89±0,04
Cows of the dairy herd	Lim	0,12–0,23	0,25–0,44	0,24–0,6	0,76–1,09
	M±m	0,17±0,01	0,34±0,02	0,35±0,04	0,86±0,03
p<		–	0,1	0,1	0,1

Note: p< – compared to pregnant cows

In ECG analysis, attention is also paid to the systolic index – the ratio of the duration of electrical systole (QT) to the cardiac cycle (R-R), which is calculated using the Bazett formula (SP=(QT:RR)-100%). It characterizes the state of the cardiac conduction system[18]. In pregnant cows, the systolic index ranges from 25,0 to 45,0% and averages 34,8±2,47%, in dairy cows – from 28,3 to 48,3% (39,5±2,17%).

An increase in the duration of the systolic index in dairy cows indicates an increase in their heart function, which is associated with a significant increase in ACP (primarily systolic)[19].

The use of special methods of cardiac examination, such as ECG and tonometry, allows detecting changes in its functioning before the appearance of clinical signs of pathology. Mostly, these changes arise due to the physiological characteristics of the cows we studied pregnancy and the beginning of productivity.

Thus, in clinically healthy high-yield cows, the heartbeat is localized, of moderate strength, the heart tones are clean, clear, and normal. The pulse rate in highly productive cows is in the range of 64-80 beats per minute, the maximum blood pressure is 100,0–140,0 mm Hg, minimum – 32,0–60,0, pulse – 53,0–93,0 mm Hg. ECG parameters within the limits established by us differ slightly from those given in the literature [20, 21], namely, a reduced R wave voltage, increased S and T; an increase in the duration of the R-R cardiac cycle and a decrease in Q-T, which is obviously due to the high productivity of cows.

The heart is the central organ of blood circulation. It meets the body's needs for oxygen due to the coordinated functioning of the hematopoietic organs and blood flow in the vessels. Therefore, in case of cardiac pathology, it is important to study the state of erythrocytopoiesis[22].

In deep-bodied clinically healthy cows (n=22), the number of erythrocytes is in the range of 5,0–8,0 T/l (6,6±0,15), in the blood of newly degenerated (n=12) and early lactation cows (n=21) – 5,2–7,2 T/l

[18] A. Rezakhani, A. A. Paphan, Seyed Shahram Shekarforoush Analysis of base apex lead electrocardiograms of normal dairy cows. *Veterinary Archives*. 2004. № 74(5). P. 351–358.

[19] Electrocardiogram assessment using the Einthoven and base-apexlead systems in healthy Holstein cows and neonates / Dario A. Cedeno, Maria L. G. Lourenço, Carmen A. B. Daza, et al. Pesq. Vet. Bras., 2016. 36(Supl.1). P. 1–7.

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[22] Cardiac pacemakers in dogs / U. Pasławska, R. Pasławski, P. Skrzypczak et al. *Electronic Journal of Polish Agricultural Universities, Veterinary Medicine*, 2000. Vol. 3, Is. 1. P. 35–42.

erythrocytes with an average value of 6,2±0,18 and 6,4±0,12 T/l, respectively (Table 6).

By calculating the standard deviation (δ= ±0,7; n=55), it was found that in 87,2 % of animals the number of red blood cells in the blood was in the range of 5,7–7,3 T/l, and 100 % – 5,0–8,0 T/l. Therefore, the latter figure can be taken as the normal range for cows (5,0–8,0 T/l).

The hemoglobin content in the blood of deep-calving clinically healthy cows averaged 120,4±2,12 g/l (100,4–139,2; Table 5). Calculations of the standard deviation showed that 95 % of cows should have hemoglobin limits in the range from 100,0 to 140,0 g/l. This is somewhat higher than the values reported in the literature (95–125 g/l)[23], and is obviously due to the increased oxygen demand of the body of highly productive cows. The hemoglobin content in the blood of newly calved cows averaged 114,6±2,8 g/l (95,6–131,2), and in dairy cows – 118,5±2,0 g/l (95,6–128,8).

Since the difference between the indicators of different physiological groups is not significant (p<0,1), according to our calculations (δ = ±10,0; n = 55), the physiological limits of hemoglobin content in the blood are in the range from 100,0 to 136,0 g/l. Within these limits are 97,4% of all hemoglobin values. A significant deviation of the upper limit is associated with the increased oxygen demand of the body of highly productive cows [209, 212]. In one deep-pregnant animal (2,6 %), hyperchromemia was detected at the level of 139,2 g/l, but other indicators of erythrocytopoiesis (red blood cell count, HbE and mean erythrocyte volume) were within the physiological range (7,9 T/l, 17,6 pg and 59.5 μm3, respectively). The increase in hematocrit value to 0,47 l/l is proportional to the number of red blood cells.

Mean corpuscular hemoglobin (MCH) in clinically healthy deep-calving cows was in the range of 15,4–20,6 pg with an average value of 18,2±0,29 pg, newly calving cows – from 16,3 to 20,2 pg (18,5±0,35), in early lactation cows – 15,6–19,8 pg (18,5±0,2) (Table 6). Having calculated the standard deviation in all groups (δ=±1,2), we set physiological limits of VGE for high-yielding cows – 15,5–21,0 pg.

An objective indicator of erythrocytopoiesis is the hematocrit value – the ratio of red blood cell volume to the total volume of blood taken [209–211]. In clinically healthy deep-calving cows, the average hematocrit value was 0,38±0,01 l/l (0,32–0,47 l/l), in newly calving cows – 0,35±0,01 l/l (0,29–0,41), and in the group of early lactation cows – 0,34±0,01 l/l (0,27–0,43 l/l), which is significantly lower (p<0,05) than in deep-calving

[23] Клінічна діагностика внутрішніх хвороб тварин / за ред. В. І. Левченка. Біла Церква, 2004. 608 с.

cows (Table 7). This may be due to an increase in the amount of blood plasma used for milk secretion in dairy cows.

Table 6

Indicators of erythrocytopoiesis in clinically healthy high-yield cows

Indicators		Deep-pregnant cows	Newly calved cows	Early lactation cows
Hemoglobin, g/l	Lim	100,4–139,2	95,6–131,2	98,0–128,8
	M±m	120,0±2,12	114,6±2,8	119,2±0,94
	M±δ	110,0–130,0	105,6–123,6	109,5–127,5
	M±2δ	100,0–140,0	96,6–132,6	100,5–136,5
Number of red blood cells, T/l	Lim	5,8–8,0	5,2–7,2	5,2–7,2
	M±m	6,6±0,15	6,2±0,18	6,4±0,12
	M±δ	5,9–7,3	5,6–6,8	5,9–6,9
	M±2δ	5,2–8,0	5,0–7,4	5,4–7,4
MCH, pg	Lim	15,4–20,6	16,3–20,2	15,6–19,8
	M±m	18,2±0,29	18,5±0,35	18,5±0,25
	M±δ	16,9–19,5	17,3–19,7	17,4–19,6
	M±2δ	15,6–20,8	16,1–20,9	16,3–20,7

The physiological limits of hematocrit value (δ=±0,04, n=55) for highly productive cows are in the range from 0,27 to 0,45 l/l, which includes 99,1 % of all values.

The hematocrit value depends on two indicators: the number of red blood cells and their average volume. The average volume of red blood cells in deep-calving cows is 57,4±1,33 (46,1–67,7) μm3, in newly calved cows – 57,0±1,76 (44,4–63,3) μm3, and in early lactation cows – 53,6±1,39 μm3 (41,7–66,2) (Table 7), which is significantly lower ($p<0,05$) than in deep-calving animals.

According to the calculations of the standard deviation (δ= ±6,0; n=55), the average red blood cell volume in 95 % of high-yielding cows should be in the range from 44,0 to 68,0 μm3. According to the results of our research, 98,3% of such cows were.

In high-yielding cows, red blood counts are somewhat higher than the norms generally accepted in the literature[24], with the exception of the hematocrit value. This is due to the increased oxygen and nutrient requirements of high-yield cows[25].

Table 7

Indicators of hemocytopoiesis in clinically healthy high-yield cows

Indicators		Deep-pregnant cows	Newly calved cows	Early lactation cows
Hematocrit value, l/l	Lim	0,32–0,47	0,29–0,41	0,27–0,43
	M±m	0,37±0,01	0,35±0,01	0,34±0,01*
	M±δ	0,33–0,41	0,31–0,39	0,3–0,38
	M±2δ	0,29–0,45	0,27–0,43	0,26–0,42
Average red blood cell volume, μm3	Lim	46,1–67,7	44,4–63,3	41,7–66,2
	M±m	57,4±1,33	57,0±1,76	53,6±1,39*
	M±δ	52,1–62,7	51,0–63,0	47,2–60,0
	M±2δ	46,8–68,0	45,0–69,0	40,8–66,4
The number of leukocytes, G/l	Lim	5,8–8,0	5,2–7,2	6,0–8,5
	M±m	6,6±0,15	6,9±0,24	7,0±0,18
	M±δ	5,6–7,6	6,0–7,9	6,0–8,0
	M±2δ	4,6–8,6	5,1–8,8	5,0–9,0

Notes: * – p< 0,05 compared to deep-pregnant cows

The number of leukocytes in the blood of deep-calving clinically healthy cows is in the range of 5,8–8,0 G/l with an average value of 6,6±0,15 G/l, in newly calving cows – 5,2–7,2 G/l (6,9±0,24 G/l), in animals of early lactation – 6,0–8,5 G/l (7,0±0,18 G/l; Table 7).

The total number of leukocytes in the blood of high-yielding cows of all physiological groups ranges from 5,0 to 9,0 G/l. The calculation of the

[24] Клінічна діагностика внутрішніх хвороб тварин / за ред. В. І. Левченка. Біла Церква, 2004. 608 с.

[25] Козир В. Резерви збереження максимальної молочної продуктивності молочних корів *Тваринництво України*, 2005. № 4. С. 2–4.

standard deviation (δ = ± 1.0, n = 55) showed that 95 % of cows should be in the range of 4,8–8,8 G/l.

The morphological study of the blood of high-yielding cows revealed insignificant fluctuations in hemoglobin content, red and white blood cell counts, hematocrit values and red blood indices between different technological groups. In deep-calf cows, an increase in hemoglobin concentration is a physiological phenomenon. In dairy cows, changes in red blood counts are caused by the increased need for nutrients for milk production.

Since the results of hemocytopoiesis presented by us were obtained on a large number of cows (n=55) and differ slightly only in some indicators (hematocrit value and average red blood cell volume) between different technological groups, then, summarizing them, taking into account the values of the standard deviation, we can draw the following conclusion about the limits of physiological fluctuations: hemoglobin content in high-yielding cows should be 95,0–136,0 g/l, red blood cell count – 5,0–8,0 T/l, leukocytes – 5,0–9,0 G/l, hemoglobin content in one red blood cell – 15,5–21,0 pg, hematocrit value – 0,27–0,45 l/l, average red blood cell volume – 44,0–68,0 μm3.

The pulse rate in high-yield cows is within narrower limits (64–80 beats/min) than that given in the literature (50–80) [210], and the minimum value (64) is slightly higher. Obviously, this is due to the need to more intensively supply the body with oxygen and nutrients, which is confirmed by the maximum value (140 mm Hg) of systolic blood pressure. The main tooth in the frontal leads is tooth S. It has a much higher voltages than tooth R. According to our results, its voltages exceed those reported in the literature [97]. It is obvious that the processes of depolarization in the ventricular myocardium of high-yielding cows are more intense. This is also confirmed by a longer ST interval and a high T-wave voltage, which characterizes the repolarization period and depends on the state of myocardial metabolism.

Thus, the results of pulse rate, arterial blood pressure, ECG, hemoglobin content in the blood of highly productive cows are somewhat different from those generally accepted in the literature, which is due to the physiological characteristics of their body, which are aimed at ensuring high metabolic rate.

2. Prevalence and main causes of myocardial dystrophy in high-yield cows

Achieving high dairy productivity in cows primarily depends on adequate feeding combined with sufficient genetic potential and optimal housing technology that meets the biological characteristics of the animals.

The organization of cow feeding and exploitation is based on scientific principles, i.e., on knowledge of the biological needs of animals according to their physiological state, age, body weight, and level of productivity[26].

In industrial complexes, it is especially important to strictly adhere to the technology of animal rearing, the violation of which can cause undesirable changes in systems and organs. Deviations from optimal feeding and housing conditions, along with insufficient exercise, and intensive use of animals lead to additional stress on physiological processes, which causes diseases of the cardiovascular system.

Increased milk production in cows is accompanied by activation of the cardiovascular system and increased blood filling of the mammary gland, which can lead to a weakening of heart function and the development of myocardial dystrophy based on physical overstrain[27]. For the first time, morphological changes in the heart in high-yielding cows were discovered by an outstanding scientist, pathologist V.P. Shishkov almost 50 years ago[28]. He found that dystrophic and necrotic changes predominate in the myocardium, while inflammatory processes occur in isolated cases.

Out of 107 studied deep-pregnant cows, we found 59 cows and heifers with clinical signs characteristic of myocardial dystrophy, which is 55,1% of cows of this physiological group. Such a significant spread of the disease is due to the genetically hereditary high productivity of animals, which contributes to the activation of cardiac activity and work at the limit of their capabilities[29].

Myocardial dystrophy was detected in 46,8% of heifers, and among deep-calving cows the number of diseased animals was 61,7%. The most common ICD is among cows with more than one calving. However, among the animals we studied, we found 13 deep-calving cows of the first lactation with clinical signs of MCD, which is obviously due to the use of significant myocardial energy reserves at the beginning of the productive period.

Among the cows of the first lactation, we found 35,1 % of cases of myocardystrophy, 24,4 % in the second lactation, 18,9 % in the third lactation, and 19,6 % in the fourth and higher lactation (up to the 7th lactation)

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[26] Коваль Т. Вирощування й годівля – коригуючі чинники молочної та відтворної продуктивності *Тваринництво України*, 2006. № 5. С. 13–15.

[27] Адмін Є., Король А. Технологічні аспекти організації годівлі корів кормосумішами з кормових столів в умовах безприв'язного утримання *Тваринництво України,* 2005. № 11. С. 8–13.

[28] Клінічна діагностика внутрішніх хвороб тварин / за ред. В.І. Левченка. Біла Церква, 2004. 608 с.

[29] Translocation and cleavage of myocardial dystrophin as a common pathway to advanced heart failure: A scheme for the progression of cardiac dysfunction / Teruhiko Toyo-Oka, Tomie Kawada, Jumi Nakata et al. *Proc. Natl. Acad. Sci. U.S.A.* 2004. № 101(19). P. 7381–7385.

(Table 8). That is, 64,9% of high-yielding cows with myocardial dystrophy have more than one calving.

Table 8

Prevalence of myocardial dystrophy in deep-calf cows depending on the number of lactations

Indicator	Number of lactations				In total
	First	second	third	fourth and more	
Sick animals, in total	13	9	7	8	37
in percentage	35,1	24,4	18,9	19,6	100

Among dairy cows, we found 49,7 % of animals with myocardial dystrophy, since to maintain high milk production, there is a significant load on the heart muscle[30]. Among the group of newly calving cows (1–14 days after calving), MCD was detected in 50,6 % and in early lactation – in 49,1 %. This is due to the beginning of the lactation period, when the load on the heart for the formation of colostrum and then milk increases several times.

A clinical study of cows of three technological groups (deep-calving, newly calving and early lactation cows) revealed 51,7% of animals with myocardial dystrophy and 8,3% with changes typical of hepatocardial syndrome. If laboratory tests are taken into account, the prevalence of myocardial dystrophy is 48,1% and hepatocardial syndrome is 21,8%.

The average milk yield of cows in farms is 5000–8000 kg of milk per lactation. The fat content of milk varies between farms and depends on both breed characteristics and cow feeding. Milk fat content ranged from 3,4% to 4%.

Highly productive cows achieve the highest milk yield starting from 3–4 lactations, when the average daily milk yield reaches 20–30 liters of milk or more.

In the studied clinically healthy deep-pregnant cows, the average milk yield for the previous lactation was 4430,4±440,01 kg (2549,0–8319,0), while in cows with symptoms of myocardial dystrophy – 5607,4±308,75 kg (3015,0–11106,0), and in 59,5 % of the diseased animals the milk yield exceeded 5 thousand kg of milk, while among clinically healthy cows such indicators of milk productivity were observed in 47,1 %. Among the deep-

[30] Paccioli D. Clean cows // *Research / Penn State*, 2018. Vol. 19. № 1. P. 23–29.

calving cows with MCD, the highest number of cows had a milk yield of more than 6000 kg of milk in the previous lactation (40,6%). In this group, 77,3% of animals were of the 2nd and more lactations.

Among clinically healthy dairy cows, the average daily productivity was 22,4±0,63 (17,4–28,3) kg of milk. In animals with myocardial dystrophy, milk production did not differ (22,6±0,64; 16,0–34,0 kg). In 52,6 % of dairy cows with MCD, the average daily milk yield was from 20 to 25 kg of milk, and in 21,1 % – above 25 kg.

The average milk yield in dairy cows with myocardial dystrophy during the last lactation was 6214,5±445,58 kg (3050,0–10848,0), which is significantly higher ($p<0,01$) than that of clinically healthy animals. Among the diseased dairy cows, 18 heads (81,8 %) were found to have a productivity of more than 5000 kg of milk during the last lactation. That is, the contributing factor is not the average daily productivity, but the productivity of cows per lactation, that is, a longer period of time. Thus, high milk production of cows is one of the factors that can cause damage to the heart muscle.

One of the main links in the pathogenesis of MCD is intoxication due to metabolic disorders and physical stress of the myocardium to convert 75% of the energy consumed from feed into milk, which is due to genetically inherited high milk production.

The cow housing systems in the farms where the monitoring studies were conducted have their own characteristics that affect the incidence of animal diseases.

Tethered housing implies that the livestock is constantly kept in a room during the stall period, where each animal has a separate place (stall) with a feeder and a drinker. To restrict movement, each stall has a device (tether) for fixing the cow in it, which allows animals to stand, lie down, eat feed, drink water, etc. without hindrance. In this case, almost all animal service operations take place on site in the stalls. Feed is delivered to the premises and distributed to the feeders, depending on the milk production of the cows. Water is supplied to waterers, fresh bedding is delivered and laid in the stalls, and excrement is systematically removed outside the premises. Milking is done twice a day, and the animals are allowed to go for a walk in the intervals between milking in sunny weather. In the summer, heifers are kept in the exercise yards located next to the farm[31].

In tethered dairy cows, we found 52,0% of patients with myocardial dystrophy, while in free-range cows – only 38,7%. The large-group system of keeping animals of the dairy herd helps to reduce multiple pathologies:

[31] Fowler N.O. Cardiac diagnosis and treatment. New York – San Francisco – London : Harper-Row, 1976. 1150 p.

the number of cows with heart and liver pathology is only 3,2%, while in tethered housing it is 15,0%.

For the physiological functioning of the cardiovascular system, it is necessary to support the peripheral circulatory system, in particular skeletal muscle. It is known that cows need daily exercise for normal operation. In its absence, blood stagnation occurs in the vessels, and blood flow decreases. The myocardium does not receive enough nutrients, which causes cardiomyocyte dystrophy.

Along with the traditional indicators – productivity, fat and milk yield, fertility – in industrial conditions, great importance is attached to the following qualities of cows: suitability for group housing indoors, resistance to adverse environmental factors, etc.

The regrouping of cows from the milk production shop to the premises for deep-pregnant animals and their transfer back to the dairy herd is a stressful factor that affects the condition of the heart and leads to dystrophic changes in its structure.

The predominance of primary myocardial dystrophy is due to stress factors, namely the transfer of animals from the calving shop, where they were kept in large group untethered housing, to the drying shop with a tether, when exercise is reduced to a minimum. During this period, the "trained" heart is not supported by peripheral muscles, whose movement enhances hemodynamics and tissue oxygenation. In the absence of exercise, dystrophic changes occur in the hypertrophied heart[32].

As for feeding, its first and most important condition is the complete satisfaction of all the animal's energy needs, which is necessary to ensure the functioning of the cardiovascular and respiratory systems, the synthesis of cellular proteins in the cow's body during its relative rest in comfortable conditions[33].

World science and practice show with great conviction that the increase in milk production of cows is determined by rational feeding at a high level of organization of animal husbandry technology. The dry matter content of the feed determines the concentration of energy, nutrients and minerals in the rations, which allows to regulate the intensity, direction of feeding and productivity of cows. Evaluation of rations by feed units, without taking into account the dry matter content, does not give an idea of the efficiency

[32] Francesca Bonelli, Tommaso Vezzosi, Mireille Meylan, Irene Nocera, Vincenzo Ferrulli, Carlotta Buralli, Rosalba Tognetti Comparison of smartphone-based and standard base-apex electrocardiography in healthy dairy cows *J Vet Intern Med.* 2019. № 33. С. 981–986.

[33] Cardiac arrhythmias innormal Holstein heifers / Machida NY, Okamata Y, Minami S, et al. *J Jap Vet Med Assoc.*, 1991. № 44. P. 1176–1179.

of their use, especially in industrial milk production in the case of group rationing of cows[34].

It is known that due to a lack of protein in diets, digestibility and feed utilization deteriorate, cow productivity decreases by 30–35%, and product quality decreases, which leads to an increase in milk cost[35]. Sugar and starch are optimal substrates for microorganisms that inhabit the fore stomachs of ruminants. The lack of these easily fermentable carbohydrates in the diet leads to a decrease in nutrient absorption, impaired carbohydrate-lipid metabolism, and the development of ketosis and acidosis. A certain ratio of potassium, sodium, and calcium ions is necessary for the physiological rhythm of cardiac activity[36].

In the winter-spring period, dry cows at OJSC Terezino are fed mainly with concentrated feed, which makes up 53,8 % of the total nutritional value of metabolizable energy. There is little roughage in the diet structure – 6,1%, which causes an imbalance of nutrients in the rumen content, and the ratio of sugar to digestible protein is 1,11: 1 (the norm is 1,0–1,1: 1). The ratio of calcium to phosphorus is low – 1,41: 1 (the norm is 1,6–1,8: 1), which affects the absorption of these macronutrients in the body of cows (Table 9).

In the winter-spring period, the diet of dry cows of LLC "Agrofirma "Glushky" is dominated by juicy feed (67,3% of the total nutritional value of the diet in terms of metabolizable energy), roughage and concentrated feed were 18,9 and 13,8%, respectively. The cows are mostly provided with nutrients, but there is a lack of some of them. For example, the ratio between easily fermentable carbohydrates and digestible protein is low (1,21:1, while the norm is 2,1–2,2:1), which has a negative impact on the rumen microflora. The ratio of calcium to phosphorus in the diet is 5,2: 1. With this ratio, the body is not able to fully absorb them from feed, which can cause postpartum hypocalcemia and osteodystrophy.

The diet of dry cows in the stall period lacks zinc, which reduces the activity of alkaline phosphatase and LDH, which include this trace element. The lack of cobalt and iron negatively affects hematopoietic function, iodine – the function of the thyroid gland, whose disorders impair heart function[37]. Insufficient intake of cholecalciferol in pregnant cows reduces the concentration of calcium in the body, which is necessary for cardiomyocyte

[34] Electrocardiography in horses – Part 1: How to make a good recording / T. Verheyen, A. Decloedt, D. De Clercq, et al. *Vlaams Diergeneeskundig Tijdschrift*, 2010. № 79. P. 331–336.

[35] Ветеринарна клінічна біохімія / за ред.. В. І. Левченка і В. Л. Галяса. Біла Церква, 2002. 400 с.

[36] Іванченко М. М., Рубан Ю. Д. Годівля та утримання високопродуктивних корів. К. : Урожай, 1991. С. 4–10.

[37] Fowler N. O. Cardiac diagnosis and treatment. New York – San Francisco – London : Harper-Row, 1976. 1150 p.

contraction. Lack of carotene in cows leads to damage to the mucous membranes of the digestive, respiratory and skin organs (Table 9).

Feeding of pregnant cows is very important, as part of the nutrients is spent on building the fetal body and its development[38]. Insufficient intake of calcium, zinc, cobalt, iodine, carotene, vitamin D causes the excretion of these elements from the cow's body, which are necessary for the normal functioning of the myocardium. After calving, this causes a significant spread of MCD and hepatocardial syndrome among newly calving cows (up to 66,2%).

In the summer, the diet of dry cows at OJSC Terezine is dominated by juicy fodder, which accounts for 59,3% of the total nutritional value of the diet in terms of metabolizable energy (mainly due to the green mass of corn). The amount of easily digestible carbohydrates (sugar and starch) is 3.9 times higher than the amount of digestible protein. 53,9% of the digestible protein requirement does not allow for proper protein metabolism. The lack of calcium and phosphorus in the diet leads to insufficient intake of these elements in the animal's body and, accordingly, to bone tissue and cardiomyocyte excitability disorders.

The deficiency of trace elements such as zinc (92,7% of the requirement), cobalt (55,2%), iodine (60,6%), as well as carotene (84,4%) and vitamin D (19,0%) causes osteogenesis, endocrine gland function, and reduces the biological activity of metal-containing enzymes.

The summer ration of cows in the drying shop of PE "Agrofirma Svitanok" is unbalanced in almost all respects. It contains a sufficient amount of roughage (hay – 11,3%, straw – 14,6%). The diet contains a significant amount of concentrated feed – 37,6%. The excess of easily fermentable carbohydrates over digestible protein (3.06:1) causes disruption of biochemical processes in the rumen. Indirectly, this effect also affects the cardiovascular system, as it can disrupt both energy and plastic metabolism in the myocardium. The diet of dry cows contains a sufficient amount of calcium (101.2% of the requirement), but the lack of phosphorus (calcium-phosphorus ratio 2.25:1) reduces the absorption of these macronutrients in the intestine. Getting into the intercellular space, calcium ions cannot participate in the conduction of impulses to cardiomyocytes, which disrupts myocardial contractility[39].

Dairy cows of LLC "Agrofirma Glushky" are fed mainly with juicy and concentrated feed (62,1 and 35,7% of nutritional value, respectively).

[38] Левченко В. І. Проникніться любов'ю до голштинів. Годівля корів з точки зору профілактики внутрішньої патології *Здоров'я тварин і ліки*, 2005. № 6. С. 4–5.

[39] Krown K. A., Page M. T., Nguyen C. Tumor necrosis factor alfa-induced apoptosis in cardiac myocytes: involvement of the sphingolipid signaling cascade in cardiac cell death *J. Clin. Invest.*, 1996. Vol. 98. P. 2854–2865.

The structure of the diet is mixed – concentrate-silage-haylage. The amount of digestible protein significantly exceeds the content of easily fermentable sugars in the diet (sugar + starch: digestible protein – 1,27: 1, with a norm of 2,0–2,5: 1). The amount of calcium and phosphorus is sufficient, and their ratio of 1.82:1 is optimal.

The diet of dairy cows at PE "Agrofirma Svitanok" contains a large amount of juicy and concentrated feed, which accounts for 51,9 % and 34,9 % of its total nutritional value, respectively. The structure is mixed. The ratio between the sum of sugar and starch and digestible protein is low and amounts to 1,72:1, and the ratio between calcium and phosphorus is low for high-yielding cows – 1,67:1 (the norm is 1,8–2:1), which provokes calcium resorption from bones. The diet is deficient in manganese (87,7% of the requirement), cobalt (68,0%), iodine (69,6%) and vitamin D (77,0%).

Manganese deficiency causes impaired osteogenesis and hemoglobin formation. Cobalt is a component of vitamin B12, which stimulates the absorption of nitrogen in the body. Its deficiency causes hyperchromic anemia, mucous membrane and skin disorders. Iodine is a component of thyroid hormones, and its deficiency disrupts its function, which causes changes in the cardiovascular system. Vitamin D deficiency leads to insufficient absorption of calcium and phosphorus from feed, which are the main components of the mineral part of bone tissue[40].

The diet of dairy cows of LLC "Agrofirma "Glushky" in the summer is characterized by a low content of roughage (0,5 %) and a predominance of juicy feeds – 64,8 % of the total nutritional value of the diet. Lack of sugar and starch (76,1 and 75,2%, respectively) with excessive protein feeding (sugar + starch to protein – 1,03:1) negatively affects both milk fat content and metabolic processes in the rumen. The oversaturation of the diet with calcium against the background of a reduced phosphorus content (Ca:P = 2,3:1) does not allow for optimal absorption of these macronutrients, which may be the cause of their deficiency in body tissues.

The summer ration for dairy cows at OJSC Terezine is highly concentrated (49,4% of the total nutritional value), containing insufficient dry matter, sugar and fiber. The ratio of sugar and starch to protein is 2,1: 1, calcium to phosphorus – 1,35: 1, which obviously impairs the absorption of macronutrients from feed.

The insufficient amount of trace elements in the diet: manganese (87,7% of the requirement), cobalt (68,0%) and iodine (30,1%) suppresses thyroid function. As a result, acidic glycosaminoglycans are deposited in the heart,

[40] Норми годівлі і поживність кормів для різних видів сільськогосподарських тварин : довідник / Г. В. Проваторов, та ін. Суми : ТОВ ВТД «Університетська книга», 2007. 488 с.

lungs, kidneys, and serous cavities, which change the colloidal structure of their connective tissue, where dystrophic changes develop.

Unbalanced feeding of deep-calving and dairy cows, impaired calcium to phosphorus ratio (normally 1,8–2:1) and insufficient absorption of energy and plastic materials necessary for the physiological functioning of the heart are among the factors that cause dystrophic changes in the myocardium.

In addition to feeding, heart disease can be the result of other diseases. Among the non-communicable diseases on farms, the most common are purulent necrotic lesions of the limbs, ketosis, and hepatodystrophy. We found 39 cows with limb lesions, 15 with signs of ketosis (the appearance of ketone bodies in the urine), which is 26,0 and 10 % of the total number of patients with myocardial dystrophy, respectively. 24 animals (8,3 %) with symptoms of hepatodystrophy were allocated to the group of cows with hepatocardial syndrome (Table 9). Among the group of dairy cows with myocardial dystrophy, we found 38 animals (25,3%) in which laboratory tests of blood serum revealed changes typical of hepatodystrophy (hyper- and dysproteinemia).

Among obstetric and gynecological diseases, the most common are pathologies of childbirth, namely stillbirth, abortion, large-forced birth (5,3% of the total number of sick animals), and endometritis (37,3%). Many cows suffer from mastitis (36,0%; Table 9). Inflammation of the mammary gland is most common at Terezine, as the system of milking and keeping dairy cows has changed, which has affected the physiological state of the udder. These diseases cause the accumulation of toxic metabolic products in the body of highly productive cows, which enter the heart with the bloodstream. It is known that 10% of all circulating blood enters the coronary arteries, which supply the heart muscle with nutrients. Toxins enter the intercellular space and penetrate cardiomyocytes, disrupting their metabolism and energy. This leads to a decrease in the functional activity of the heart, which causes a violation of the cell structure.

Thus, myocardial dystrophy has a multi etiologic character, and its course is complicated by other diseases. The largest number of cows with myocardial dystrophy was found in the group of deep-calving and newly calving cows, respectively 55,1 and 50,6 % of the total number of animals in the group. Its development is influenced by the genetically determined high milk yield of cows; the most common MCD is in the case of milk yields of more than 5000 kg of milk per lactation (59,5% of diseased cows in early lactation). In addition to heart disease (52,0%), 15,1% of high-yielding cows develop complex heart and liver disease under tethered conditions (Table 9).

Table 9

Prevalence of non-communicable diseases in high-yield cows with myocardial dystrophy

Indicator	Total number of cases	including ketosis	Endometritis	Mastitis	Purulent-necrotic lesions of the extremities	Hepatosis	Endo-metritis + mastitis
Number of heads	150	15	56	54	39	24	48
In percentage terms	100	10,0	37,3	36,0	26,0	8,3	32,0

An imbalance of the diet in terms of nutrients: lack of easily digestible carbohydrates, excessive protein feeding, impaired calcium intake, lack of manganese, cobalt, iodine, carotene and vitamin D are factors that contribute to the development of myocardial dystrophy among high-yield cows. The main cause of MCD is intoxication, which develops as a result of metabolic disorders (ketosis, osteodystrophy, metabolic acidosis), liver structure and function, limb damage, stillbirths, abortions, large-forced births, endometritis, and mastitis. Some of these diseases have common causes and pathogenetic mechanisms with ICD, such as ketosis and hepatodystrophy, i.e. multiple pathology develops. Others (endometritis, mastitis, purulent necrotic processes in the fingers), occurring simultaneously with ICD, complicate the pathological process in the myocardium, as there is a massive absorption of toxins and tissue decay products.

3. Clinical and functional diagnosis of myocardial dystrophy in high-yield cows

In highly productive cows, pathologies of the liver, kidneys, fore stomach, and metabolic diseases are often recorded, which negatively affect the cardiovascular system[41]. To characterize the state of the cardiovascular system, we used general clinical (examination, palpation, auscultation) and special (measurement of ACP, ECG) research methods. Obviously, in different physiological periods (deep pregnancy, 1–14 days after delivery), functional changes will be slightly different. Clinical and functional diagnostics of high-yielding cows with myocardial dystrophy was performed

[41] Characterization of MB creatine kinase isoform conversion in vitro and in vivo in dogs / J. J. Billadello, H. L. Fontanet, A. W. Strauss and D. R. Abendschein *J. Clin. Invest,* 1989. № 83(5). P. 1637–1643.

on 97 animals, of which 47 were deep-calving, 25 were newly calving and 25 were early lactation cows.

During a clinical study of 97 highly productive cows with myocardial dystrophy, there was no edema in the underarm and limb area. Palpation of the chest in the heart area revealed a weakening of the heartbeat in 44,3% of the animals.

In 47 high-yielding deep-bodied cows with MCD, we found the following changes in tones: amplification – in 20; weakening – in 15 and splitting – in 12 animals (Table 10).

In the group of newly carcinogenic cows (25), 4 animals were found to have an increase, 10 – with weakening and splitting of tones, in one animal (4,0 %), a bifurcation of the first tone was found (Table 10).

Auscultation of the hearts of 25 early lactation cows with MCD revealed the following changes in tones: amplification – in 6; weakening – in 13 and splitting – in 6 animals (Table 10).

Thus, the amplification of tones, which is characteristic of the first stage of myocardial dystrophy, was found in 30 animals, which is 30,9 % of all diseased cows, but the largest proportion of them – 42,6% was among deep-calving cows. This indicates a deepening of the pathological process, when structural changes in cardiomyocytes and cells of the conduction system of the heart develop in the myocardium.

Table 10

Changes in heart tones in highly productive cows of different technological groups

Changes in heart tones	Deep-pregnant cows		Newly calved cows		Early lactation cows	
	Heads	in percent.	heads	in percent.	heads	in percent.
Weakening tones	15	31,9	10	40	13	52
Strengthening tones	20	42,6	4	16	6	24
Tone split	12	25,5	10	40	6	24
Tone bifurcation	–	–	1	4	–	–

One of the indicators of the state of the cardiovascular system is the heart rate (HR)[42]. We found that in deep-bodied and newly degenerated cows with MCD, the heart rate averaged 80±1,05 and 79±1,19 beats/min (62–98 and

[42] Методи лабораторної клінічної діагностики хвороб тварин / за ред. В. І. Левченка. Київ : Аграрна освіта, 2010. 437 с.

68–98 beats/min), which is significantly higher (p<0,001) than that of clinically healthy cows of these technological groups (71±0,83 and 72±0,7 beats/min). Tachycardia (82–98 heartbeats per minute) was detected in 38,3 and 28,0 % of the diseased animals, respectively.

In cows with myocardial dystrophy of early lactation, the heart rate was 82±1,29 with fluctuations of 64–98 beats per minute (in clinically healthy cows 72±0,74; p<0,001). In 15 sick animals of this technological group (60,0 %), the heart rate was higher than normal and ranged from 82 to 98 beats/min.

Thus, an increase in heart rate was diagnosed in 38,3 % of dry cows, 28,0 % of newly calved cows and 60,0 % of cows in the parturition group.

According to many authors [6, 8, 14, 24, 26, 119], heart failure causes changes in the lungs, which is manifested by an increase in respiratory rate. According to the results of our studies, the respiratory rate in cows with myocardial dystrophy was in the range of 14 to 30 respiratory movements/min, i.e., it was the same as in clinically healthy cows (Table 11).

Among the various methods proposed for the diagnosis of disorders of the cardiovascular system of animals, arterial blood pressure is often used in veterinary practice [92], which indirectly reflects the state of blood circulation in the body [93].

Table 11

Respiratory rate in high-yielding cows with myocardial dystrophy (respiratory movements/min)

Group of cows		Deep-pregnant cows	Newly calved cows	Early lactation cows
Clinically healthy	Lim	16–28	14–28	16–30
	M±m	22±0,49	22±0,7	23±0,74
Patients with MCD	Lim	16–30	16–30	14–30
	M±m	23±0,55	22±0,73	22±0,84
	p <	0,1	0,1	0,1

Note: p < – compared to clinically healthy animals

The results of tonometry indicate that in patients with myocardial dystrophy of high-yielding deep-calf cows, systolic and pulse blood pressure were 113,6±2,03 (90,0-140,0) and 67,0±2,03 (40,0-100,0) mm Hg, respectively, which is significantly lower (p<0.01) than in clinically healthy animals (Table 12). Diastolic blood pressure was 46,6±1,3 mm Hg with

fluctuations from 30,0 to 80,0 mm Hg and tended to increase compared to clinically healthy cows (in healthy cows – 46,0±1,55 mm Hg). A decrease in SBP against the norm (90,0 mm Hg) was found in two cows (4,3%). At the lower limit of the norm (100,0 mm Hg), this indicator was in 29,8 % of animals, indicating a decrease in myocardial contraction force. An increase in DBP was found in 19,1 %.

Table 12

Arterial blood pressure parameters in highly productive cows with myocardial dystrophy

Clinical condition of cows	Arterial blood pressure, mm Hg		
	systolic (SBP)	diastolic (DBP)	pulse (PAP)
Deep-pregnant cows			
Clinically healthy	121,0±1,67	46,0±1,55	74,0±1,55
Patients with myocardial dystrophy p <	113,6±2,03 0,01	46,6±1,3 0,1	67,0±2,03 0,01
Newly calved cows			
Clinically healthy	120,0±2,13	47,0±1,88	73,0±2,77
Patients with myocardial dystrophy p <	109,6±3,13 0,01	47,2±1,69 0,1	62,4±3,43 0,01
Early lactation cows			
Clinically healthy	119,0±1,94	46,0±1,29	73,0±2,37
Patients with myocardial dystrophy p_2 <	106,8±2,87 0,001	41,6±1,6 0,05	65,2±3,17 0,05

Note: p < – compared to clinically healthy animals

Among the newly degenerated cows with myocardial dystrophy, SBP and DBP were, respectively, 109,6±3,13 (90,0-140,0) and 62,4±3,43 mm Hg (40,0–90.0), i.e., significantly lower ($p < 0,01$) compared to clinically healthy animals. A decrease in systolic and pulse ACP was detected in 12,0 and 20,0 % of the diseased animals, respectively. DBP averaged

47,2±1,69 mm Hg (30,0-60,0), and compared to clinically healthy cows tended to increase (Table 12).

In the group of sick cows of early lactation, the indicators of systolic, diastolic and pulse blood pressure were 106,8±2,87 (90,0-140,0) mm Hg. 41,6±1,6 (30,0-60,0) and 65,2±3,17 (40,0-100,0) mm Hg. We found a significant decrease in them compared to clinically healthy animals ($p2 < 0,001$; $p2 < 0,05$; $p2 < 0,05$) (Table 12).

A decrease in SBP was detected in 24,0 % of diseased cows. An increase and decrease in the indicators of PAT were found in 4,0 and 8,0 % of diseased animals, respectively.Thus, clinical studies have shown that myocardial dystrophy in highly productive cows is characterized by tachycardia, weakening of the heartbeat, changes in heart sounds, and a decrease in systolic and pulse blood pressure.

4. Electrocardiogram parameters in high-yielding cows with myocardial dystrophy

The study of myocardial electrical activity for the diagnosis of myocardial dystrophy is very important. This method successfully resolves issues related to the diagnosis of rhythm disturbances and focal myocardial lesions. Electrocardiographic examination was performed in frontal leads[43].

During a clinical study of sick cows with ECG recording, the number of heartbeats was 82±1,32 (70-96) beats/min, which is significantly higher ($p < 0,001$) compared to clinically healthy animals (71,0±1,19 beats/min). Tachycardia (82–96 bpm) was observed in 54,8 % of the studied animals.

Analysis of the ECG of cows with myocardial dystrophy showed that their cardiac cycle was rhythmic, since the difference between the maximum and minimum duration of individual intervals (R-R) did not exceed 10 % (7,8 % on average). The rhythm is sinus, that is, the alternation of the teeth is correct.

The electrocardiogram of high-yielding cows with myocardial dystrophy in the first lead was characterized by negative P waves in 15,4 % and T waves in 69,2 % of cases, while in clinically healthy cows – in 11,1% and 77,8 %, respectively (Fig. 4). The voltages of the P and T waves tended to decrease compared to clinically healthy animals and amounted to 0,11±0,017 (0,03–0,23) and 0,13±0,026 mV (0,07–0,37), respectively. The voltage of the Q wave was expressed only in 23,1% of animals, and its average value in the group was 0,02±0,01 mV with fluctuations from 0,02 to 0,07 mV. The amplitude of the R wave was 0,03-0,47 mV (0,26±0,009) and tended to decrease compared to clinically healthy animals (0,27±0,047 mV).

[43] Шарандак П. В. Оцінка функціонального стану серця високопродуктивних корів за ЕКГ *Вісник Білоцерків. держ. аграр. ун-ту*. Біла Церква, 2006. Вип. 36. С. 175–181.

The S tooth significantly (p<0,001) decreased to 0,16±0,07 mV (0,03–0,77), compared with 0,03±0,004 mV in clinically healthy animals. The voltage of the T wave was 0,13±0,026 mV with fluctuations from 0,07 to 0,37 mV (in clinically healthy cows – 0,14±0,022 mV; Fig. 4).

In the second frontal lead, the voltages of the P and S waves had an amplitude of 0,17-0,3 mV (0,23±0,011) and 0,2-1,87 mV (0,81±0,145), respectively, and were characterized by an upward trend compared to clinically healthy animals (0,19±0,023 and 0,62±0,11 mV). The voltage of the R tooth was 0,25±0,069 (0,03-0,83) mV and tended to decrease compared to clinically healthy animals (0,27±0,073 mV). The T tooth had an average voltage of 0,54±0,072 mV with fluctuations of 0,17–1,0 mV (Figs. 4 and 5). In 18.8 % of the studied animals, a negative T wave was detected in the second lead, indicating a violation of biochemical processes in the myocardium (Fig. 6).

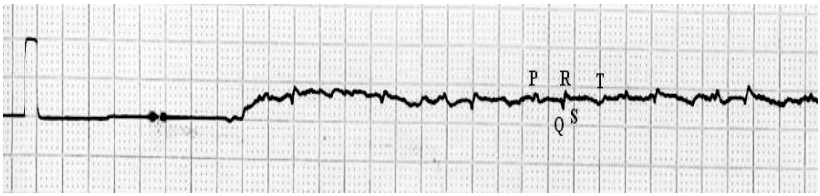

Fig. 4. Electrocardiogram in the first lead of a cow with myocardial dystrophy

The third frontal lead in cows with myocardial dystrophy was characterized by an increase in the voltage of the P, S, T, and T-waves and a decrease in Q and R compared with clinically healthy animals (Fig. 7).

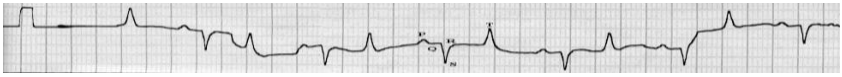

Fig. 5. Electrocardiogram of a cow with myocardial dystrophy in the second lead

In 18,8 % of cows with MCD, a negative T wave was detected in all leads, indicating significant damage to cardiomyocytes in these animals, since repolarization processes occur in the opposite direction.

Fig. 6. Negative tooth T in the second lead

Fig. 7. Electrocardiogram of a cow with myocardial dystrophy in the third lead

When analyzing ECG parameters, we found that the duration of the T-R interval in cows with myocardial dystrophy (deep-calving and dairy herd) was significantly reduced ($p<0,001$; $p<0,05$) compared to clinically healthy cows. This, in our opinion, is evidence that the heart muscle rests less in sick animals. Violation of the cardiac cycle affects the biochemical composition of cardiomyocytes, which is manifested by the release of its constituent structures: cardiotroponins, myoglobin, cytoplasmic enzymes – CC, LDH, and ACAT. Against this background, heart failure develops and, as a result, myocardial dystrophy.

The analysis of electrocardiograms widely uses the values of atrio-ventricular conduction and systolic index, which characterize the cardiac cycle in dynamics and the state of the conduction system[44].

If the absolute duration of the PQ interval did not change in deep-calving and dairy cows with MCD, then the relative atrioventricular conduction increased and amounted to 21,8±1,74 % (13,8-31,2) and 25,3±0,97 % (20,0–35,7), respectively ($p < 0,01$; Fig. 8, 9) against 19,1±0,85 and 19,8±1,35 % in clinically healthy cows. This indicates damage to the myocardial conduction system, resulting in reduced impulse transmission from the sinusoatrial node to the ventricles.

[44] Cardiac arrhythmias innormal Holstein heifers / Machida NY, Okamata Y, Minami S, et al. *J Jap Vet Med Assoc.*, 1991. № 44. P. 1176–1179.

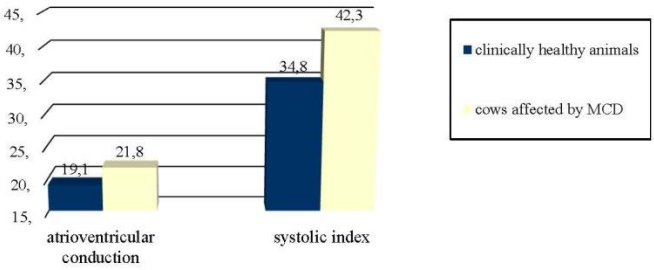

Fig. 8. Atrioventricular conduction and systolic index in deep-calving high-yield cows with myocardial dystrophy, %

The systolic index in deep-calving cows with clinical signs of myocardial dystrophy was 42,3±1,31 % (37,7–50,8) and significantly increased ($p<0,01$) compared to clinically healthy animals (34,8±2,47 %; Fig. 8). In the group of animals of the dairy herd, the average value of the systolic index was 43,1±1,45 % with fluctuations from 33,0 to 59,5 % and tended to increase compared to clinically healthy animals (39,5±2,17 %; Fig. 9).

Such changes in the systolic index, compared with clinically healthy animals, indicate impaired impulse conduction in the ventricles and depletion of myocardial cells, since the heart muscle does not have sufficient time to rest. During systole, complete repolarization of cardiomyocytes does not occur and, as a result, their dystrophy develops.

Thus, myocardial dystrophy is characterized by a decrease in the duration of the R-R cardiac cycle due to a shorter T-P diastole, the appearance of a negative T wave in all leads, and cardiac cycle disorders, which is manifested by an increase in relative atrioventricular conduction and the proportion of Q-T electrical systole in the cardiac cycle. Such changes are typical for myocardial dystrophy, as they characterize changes in the function and condition of cardiomyocytes.

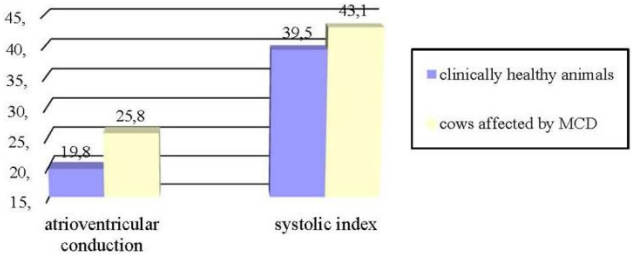

Fig. 9. Atrioventricular conduction and systolic index in dairy high-yield cows with myocardial dystrophy, %

Thus, to diagnose myocardial dystrophy in high-yielding cows, it is necessary to take into account the weakening of the heartbeat, changes in the tones of weakening, amplification, splitting and sometimes bifurcation), tachycardia (expressed in 41,2% of sick animals), a decrease in systolic blood pressure (less than 100 mm Hg). During the electrocardiographic examination, in 18,8% of the diseased animals, the T wave was negative in all leads, the cardiac cycle duration (R-R) decreased in 58,1% of animals due to a decrease in diastole (in 51,5%), the relative atrioventricular conductance increased in 50,0% of dairy cows and the systolic index in 45,5% of deep-pregnant animals.

CONCLUSIONS

In clinically healthy high-yielding cows, the pulse rate is 60–80 beats/min; breathing – 14–30 breaths. movements/min; arterial blood pressure: systolic (SBP) – 100,0–140,0 mm Hg. Art., diastolic (DBP) – 35,0–60,0 and pulse (PBP) – 53.0–93.0 mm Hg.

The electrocardiogram of clinically healthy high-performance cows in the second frontal lead is characterized by the following indicators: duration of the cardiac cycle within 0,76–1,19 s, including diastole – from 0,24 to 0,6 s, relative atrioventricular conduction and systolic index are 11,5–25,0 and 25,7–47,4%, respectively, P and T waves in all cows are electropositive (0,12–0,26 and 0,06–0,82 mV), in the ventricular QRS complex the best pronounced S wave (0,31–0,93 mV).

Myocardiodystrophy is widespread among highly productive cows: the number of diseased deep-bodied animals is on average 55,1%, newly calved and early lactation – 50,6 and 49,7%, respectively. Most often, sick cows were identified with productivity above 6000 kg of milk per lactation (50,1%) and 24 kg per day (43,3%).

The main causes of pathology are the imbalance of rations in terms of nutrients and biologically active substances, liver disease in cows, ketosis, purulent-necrotic processes in the extremities, endometritis. A favorable factor is hypodynamia during restraint.

The diagnosis of myocardial dystrophy in high-yielding cows is based on the results of a clinical and functional examination of the heart: tachycardia (82–98 beats/min), weakening, strengthening, splitting and bifurcation of tones (39,2; 30,9; 28,9 and 1,0%, respectively), a decrease in systolic arterial blood pressure, a decrease in the duration of the cardiac cycle in 54,8% of cows as a result of a decrease in the duration of diastole to 0,26±0,01 s in 51,6% of sick animals (normally 0,24–0,6 s), an increase in relative atrioventricular conduction and systolic index by 4,1 and 4,2%, a negative T wave in the second lead in 18,7% of cows.

SUMMARY

In order to diagnose myocardial dystrophy, we had to determine the physiological limits of indicators that objectively characterize the development of pathology in cardiomyocytes. These include the pulse rate and rhythm, the nature of the heart tones, arterial blood pressure, and the nature of the electrocardiogram.

The study of clinically healthy high-yielding cows showed that the blood pressure was within the following limits: SBP – 100.0-140.0 mm Hg; DBP – 32.0–60.0 and MBP – 53.0–93.0 mm Hg.

The electrocardiogram of clinically healthy high-performance cows in the second frontal lead is characterized by the following indicators: duration of the cardiac cycle within 0,76–1,19 s, including diastole – from 0,24 to 0,6 s, relative atrioventricular conduction and systolic index are 11,5–25,0 and 25,7–47,4%, respectively, P and T waves in all cows are electropositive (0,12–0,26 and 0,06–0,82 mV), in the ventricular QRS complex the best pronounced S wave (0,31–0,93 mV).

Myocardiodystrophy is widespread among highly productive cows: the number of diseased deep-bodied animals is on average 55,1%, newly calved and early lactation – 50,6 and 49,7%, respectively.

Myocardial dystrophy is based on the accumulation of toxic products in the development of hepatodystrophy, endometritis, mastitis, limb diseases, lack of motility, and stress factors. Unbalanced diets of cows with high milk production reduce the absorption of energy and plastic material, leading to the development of metabolic acidosis, ketosis and osteodystrophy.

The diagnosis of myocardial dystrophy in high-yielding cows is based on the results of a clinical and functional examination of the heart: tachycardia (82–98 beats/min), weakening, strengthening, splitting and bifurcation of tones (39,2; 30,9; 28,9 and 1,0%, respectively), a decrease in systolic arterial blood pressure and specific changes in ECG.

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