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ON THE SIZE OF THE HEART**

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THE EFFECT OF REGULAR AND IRREGULAR TACHYCARDIAS ON THE SIZE OF THE HEART

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This study is concerned with the effect of tachycardia on the size of the heart in normal unanesthetized dogs.

Meek (1) has studied the effect of changes in pulse rate on the diastolic size of the x-ray shadow of the heart. In unanesthetized dogs he obtained slow rates by the administration of morphine, followed by the injection of atropine to obtain the more rapid rates. Other dogs were given ether anesthesia and the variations in heart rate obtained by electrical stimulation of one of the vagi after double vagotomy. He found that the size of the heart decreased when the heart rate was increased. He did not obtain rates beyond 200 per minute. He thought that the effect which he observed was due to falling venous pressure, for it did not occur if the venous pressure was maintained artificially by the injection of saline-acacia solution into the left jugular vein. Hodges and Eyster (2) made x-ray photographs of the hearts of patients during periods when the rate was slow and at intervals following the injection of atropine. They were able in this way to compare the effect of rates between 60 and 130 per minute. They found that the size of the heart remained fairly constant for slight variations in pulse rate. The higher rates were accompanied by slight decrease in size of the heart.

The following studies differ from those reported by Meek in that we have been able in the first place to study the effect of tachycardia in normal unanesthetized dogs without the use of drugs to obtain changes in heart rate, in the second place we have been able to obtain very rapid rates, and in the third place we have been able to compare the effect of regular and irregular tachycardia (auricular fibrillation) on the size of the heart in the same dog.

TECHNIQUE

The detailed method of preparing the dogs for these experiments has been described in a preceding paper (3). With sterile operative technique two wire electrodes were sewed to the right auricles. Intratracheal ether anesthesia was used. The day following this preliminary operative procedure the heart was stimulated through the electrodes and the effect of regular and irregular tachycardia on the blood flow was observed (3) (4). On the next day the effect of these rhythms on the size of the heart was investigated by means of x-ray photographs of the heart.

The x-ray photographs were made according to the method described by Stewart (5) for obtaining photographs of the hearts of dogs under uniform conditions. The anticathode was placed at a distance of 2 meters from the photographic film. The dogs lay quietly on the animal board without anesthesia throughout the period of stimulation. A small needle was inserted in the skin in the midline of the anterior chest wall at the level of the heart. The anticathode was always centered on this same point before plates were exposed in case the table had shifted or the dog had moved during the experiment. Three x-ray photographs were made during each experiment: the first, during the normal rhythm; the second, after the induced rhythm had been present for 1 hour and while it was still present; and the third, a few minutes after the stimulation was discontinued. Faradic current derived from 1 to 3 dry cell batteries in the primary circuit of a Du Bois-Reymond induction coil was used to induce auricular fibrillation. Single induced break shocks thrown into the right auricle at a rapid regular rate (250 to 390 per minute) were used to induce regular tachycardia. The mechanism by which this was done has been described in a preceding paper (4). The stimuli from the apparatus in the physiological laboratory were carried to the x-ray laboratory by insulated wires running in well grounded pipes through the walls of the building. The speed at which the heart was driven in the periods of regular tachycardia was usually the same as that at which it was driven when the blood flow was studied on the preceding day. When observations were made both on the effect of regular and of irregular tachycardia in the same dog one set of observations was made during the morning and the second set in the afternoon after a rest period of 2 to 3 hours.

The method of tracing the x-ray shadows of the hearts and measuring them was that described by Stewart (5). The error of the method is less than 3 per cent; only changes greater than this are significant.

RESULTS

The effect of regular tachycardia on the size of the heart. In 4 dogs we have observed the effect of regular tachycardia on the size of the heart. The natural rates for these dogs varied between 170 and 180

per minute, although in one it was 200 per minute. The rates during artificial tachycardia were 300 per minute. The size of the heart was decreased during the period of tachycardia in all of the observations. The decrease varied between 7 and 14 per cent (table 1). In two dogs, nos. 193 and 194, further decreases were found to occur when x-rays were taken a few minutes after the stimuli had been discontinued. In dog 194 the heart had returned to its normal size 2 hours after the stimulation had been stopped.

TABLE 1
The effect of regular tachycardia on the size of the heart

Dog number	Rhythm	Heart rate per minute	Heart area	Heart area per cent of initial	Change in area <i>per cent</i>	Summary of effect
			<i>sq. cm.</i>	<i>per cent</i>		
190	Normal	180-190	57.6	100	-14	Decrease
	Regular tachycardia	300	49.8	86		
191	Normal	170-180	45.4	100	-7	Decrease
	Regular tachycardia	300	42.2	93		
193	Normal	170	75.6	100	-14 -19	Decrease
	Regular tachycardia	280-290	65.4	86		
	Normal		61.5*	81		
194	Normal	200	46.2	100	-8 -11	Decrease
	Regular tachycardia	300	42.6	92		
	Normal		41.5*	89		
	Normal		46.2†	100		

* This x-ray was made a few minutes after stimulation was discontinued.

† This x-ray was made 2 hours after the end of the stimulation period.

A comparison of the effect of regular and irregular tachycardia on the size of the heart. In 3 dogs we were able to compare in each case the effect of regular and irregular tachycardia on the size of the heart. During regular tachycardia the size of the heart decreased from 10 to 14 per cent (table 2). During auricular fibrillation the size of the heart was unchanged in two observations and was increased 11 per cent in the third. In dog 189 the size of the heart was 13 per cent less during the period of regular tachycardia (rate 300 per minute) than

it was during that of the normal rhythm (rate 160 to 170 per minute) (figs. 1, 2a and 2b). On a second occasion it decreased 14 per cent during the period of regular tachycardia. During the period of auricular fibrillation there was no alteration in the size of the heart

TABLE 2

A comparison of the effect of regular and irregular tachycardia (auricular fibrillation) on the size of the heart in the same dog

Dog number	Rhythm	Heart rate per minute	Heart area	Heart area per cent of initial	Change in area	Summary of effect
			<i>sq. cm.</i>	<i>per cent</i>	<i>per cent</i>	
189	Normal	160-170	33.8	100		
	Regular tachycardia	300	29.4	87	-13	Decrease
	Normal	210	33.3	100		
	Regular tachycardia	340	28.6	86	-14	Decrease
	Normal		26.6*	80	-20	
	Auricular fibrillation	160-170 300	32.4 32.0	100 100	0	No change
195	Normal	170-180	48.3	100		
	Regular tachycardia	380-390	43.7	90	-10	Decrease
	Normal		44.8*	92	-8	
	Normal	170-180	40.7	100		
	Auricular fibrillation	300-320	45.0	111	+11	Increase
	Normal		48.5*	119	+19	Increase
198	Normal	170-180	55.4	100		
	Regular tachycardia	300	49.4	89	-11	Decrease
	Normal		45.3*	82	-18	
	Normal	170-180	55.2	100		
	Auricular fibrillation	300	54.5	99	-1	No change
	Normal		52.6*	95	-5	

* This x-ray exposure was made a few minutes after the stimuli had been discontinued.

although the heart rate increased from 160 per minute to 300 per minute (figs. 1, 3a and 3b). In dogs 189 and 198 the tendency of the heart to decrease in size further after the discontinuance of the stimuli is again seen.

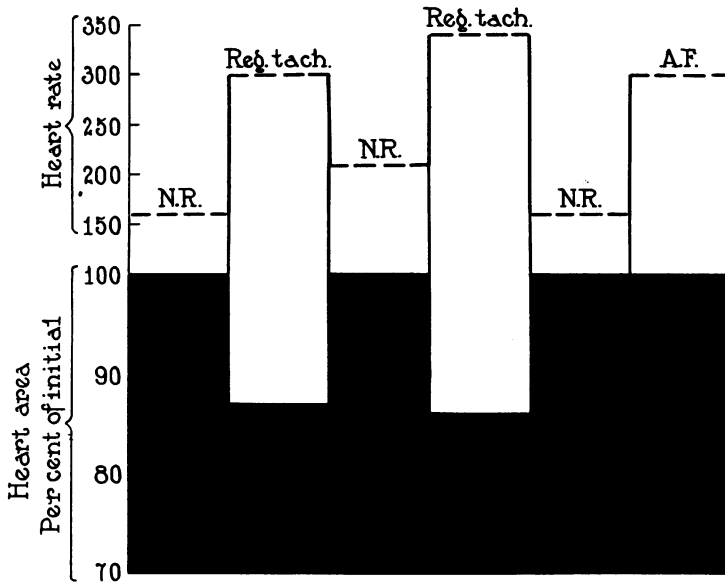


FIG. 1. In this figure is compared the effect of regular and irregular tachycardia on the size of the heart in dog 189. The size of the heart and the heart rate are seen to vary inversely during the period of regular tachycardia, while the heart area is unchanged during the period of irregular tachycardia (auricular fibrillation). N. R. = normal rhythm; Reg. tach. = regular tachycardia; A. F. = auricular fibrillation.

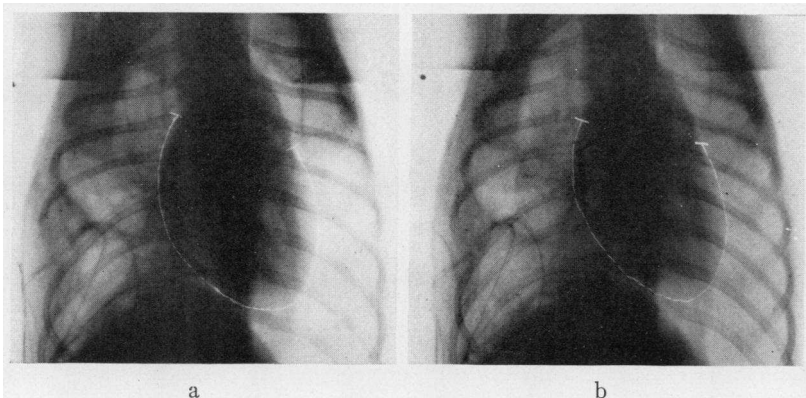


FIG. 2. Dog 189. X-ray photograph 2a was taken during the natural rate; 2b was taken after regular tachycardia had been present for 1 hour.

In 7 dogs we made 8 observations on the effect of regular tachycardia on the size of the heart (table 3). It was found that the heart decreased in size in every instance, the decrease varying between 7

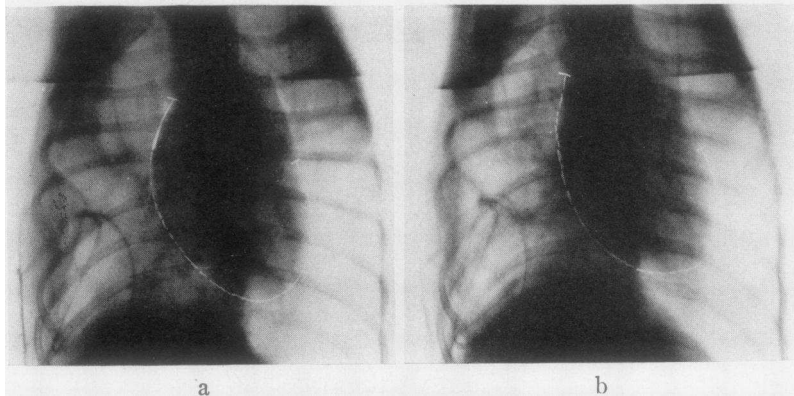


FIG. 3. Dog 189. X-ray photograph 3a was taken during the natural rate; 3b was taken after auricular fibrillation had been present for 1 hour.

TABLE 3
Summary of experiments

Rhythm	Number of observations		
	Decreased	Increased	No change
Regular tachycardia	8	0	0
Auricular fibrillation	0	1	2

and 14 per cent. In 3 dogs the effect of rapid irregular tachycardia (auricular fibrillation) was compared with the effect of regular tachycardia. The size of the heart was increased in one of these observations and remained unchanged in the other two.

DISCUSSION

The reduction in size of the heart in dogs during regular tachycardia in distinction to that found when the rate is slow is at variance with the clinical experience that on percussion the heart appears to be dilated during paroxysms of tachycardia. This may be due either to inability to detect by percussion small differences in size of the

heart, or to the difference in reaction of normal and diseased hearts to high rates. It was furthermore surprising to find a difference in the effect of regular and irregular tachycardia on the size of the heart. Stewart, Crawford and Hastings (3, 4) have shown a difference in the response of the heart to tachycardia of the regular and irregular type in that the blood flow was always decreased during auricular fibrillation but was usually unchanged during regular tachycardia. The difference in the effect of these two mechanisms on the size of the heart is another indication of the difference in functional response of the heart to these two rhythms. What the significant correlation is, we are unable to say. There may be a connection on the one hand between the decreased blood flow in auricular fibrillation and the unchanged or increased size of the heart, or on the other between the unchanged blood flow in regular tachycardia and the decreased size of the heart. In this connection Meek (1) thought that the decrease in size of the heart which he observed during increased pulse rate was due to a failure to maintain venous pressure, that is to say, to inadequacy of the venous return to the right auricle. We have not ascertained whether this factor plays a rôle during auricular fibrillation. If the venous return remains uniform and contraction of the heart adequate, a reduction in the volume of inflow blood per beat may occur during the increased heart rate. The shadow of the heart would then decrease by the decrease in the volume of the inflow blood.

SUMMARY

We have observed the effect of tachycardia on the size of the x-ray shadow of the heart in normal unanesthetized dogs. We have found that:

1. During regular tachycardia a decrease in the size of the heart occurs.
2. During irregular tachycardia (auricular fibrillation) the size of the heart is unchanged or is increased.

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