

STUDIES ON HUMAN CAPILLARIES

V. OBSERVATIONS IN CASES OF HEART DISEASE WITH REGULAR RHYTHM

By J. HAMILTON CRAWFORD

WITH THE TECHNICAL ASSISTANCE OF H. ROSENBERGER

(From the Hospital of the Rockefeller Institute for Medical Research, New York)

(Received for publication April 1, 1927)

In previous studies of the capillary circulation it was found that changes in the calibre of the capillaries took place continuously, both in health when the rhythm of the heart is regular, and in auricular fibrillation. The extent of these changes appeared to depend on the state of circulatory compensation and was independent of the rate or regularity of the pulse. Similar variations were observed in advanced decompensation both in cases of regular and of irregular rhythm. The present investigation was undertaken to study the changes which take place in heart disease with regular rhythm from the early to the late stages of the disease. Weiss (1) found in his studies of the capillaries in living subjects that cases of mitral insufficiency without cardiac decompensation showed a normal picture, while in the early stages of mitral stenosis a distinct slowing of the stream was observed. Cases of cardiac decompensation, however, showed marked dilatation of the venous limb and the blood stream was slow and had a granular appearance. These findings were in the main confirmed by Schur (2), Jürgensen (3), Neumann (4), Secher (5), Freedlander and Lenhart (6). Secher, however, described a normal capillary picture in this condition in spite of symptoms of cardiac insufficiency. Hisinger-Jagerskiöld (7) studied a large number of cases of valvular and myocardial heart disease with regular rhythm. He stated that cases with full compensation or with only slight decompensation did not differ from normal subjects but those with clinical signs of decompensation as a rule showed the changes described by Weiss in this condition. He

further described a group of cases which showed congestion of internal organs but otherwise no clinical signs of cardiac decompensation. In these the size of the loops was normal and the picture closely resembled that which the author associated with anemia.

The results to be described are based on the study of eight cases of heart disease with regular rhythm, seven of which were of rheumatic origin while the other was one of chronic myocarditis. These cases varied in their severity from a degree in which a heart lesion had just developed to one in which cardiac decompensation was marked. Cinematographic observations of the capillaries at the nail fold and simultaneous electrocardiograms were made. Synchronous points were recorded both on the photographic and the electrocardiographic films. The details of taking the cinematographic exposures and the method employed in their study have been reported in previous papers of this series (8, 9). The technique used in recording synchronous points on the cinematographic and electrocardiographic films has also been described in a previous paper (10).

The size of the loops. There was marked variation in the size of the loops in the same subject and differences were also seen between individual subjects. The state of compensation markedly affected the size of the loops, especially the venous limb. The average size of the arterial limb in early cases was from 0.014 to 0.015 mm., while that of the venous was from 0.015 to 0.016 mm. In advanced cases, the arterial limb varied from 0.015 to 0.017 mm. and the venous from 0.017 to 0.018 mm. The early cases thus presented a picture such as had been observed in normal individuals while the advanced cases resembled that seen in auricular fibrillation with clinical signs of decompensation. The values given are those of most of the loops measured, and although larger and smaller loops were studied the changes observed were similar in all.

Variations in calibre. Variations in the diameter of the loops of about equal extent in both the arterial and venous limbs took place in the same subject from moment to moment. The magnitude of these changes varied in the loops of the same subject and also in different subjects. The alterations were comparatively small, however, compared to the total breadth of the limb which remained approximately the same. Their magnitude was definitely influenced by the state of

cardiac compensation. In the early stages the variations were less marked than in the later stages (figs. 1 and 2).

Evidence of independent contractility of the capillaries. Curves which were prepared in a manner similar to those described in previous papers in this series have been studied to see whether there was evi-

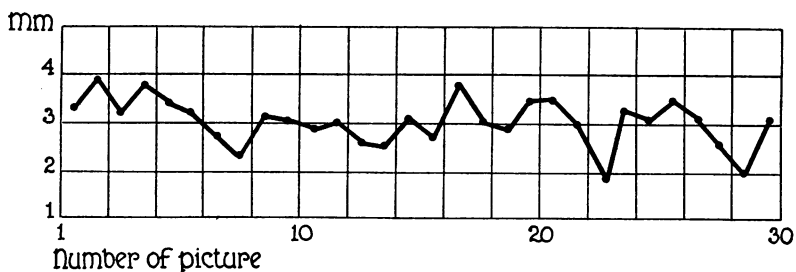


FIG. 1. THE CHANGES ARE SHOWN WHICH TAKE PLACE IN THE DIAMETER OF THE ARTERIAL LIMB OF A CAPILLARY IN AN EARLY CASE OF MITRAL STENOSIS. $\times 350$

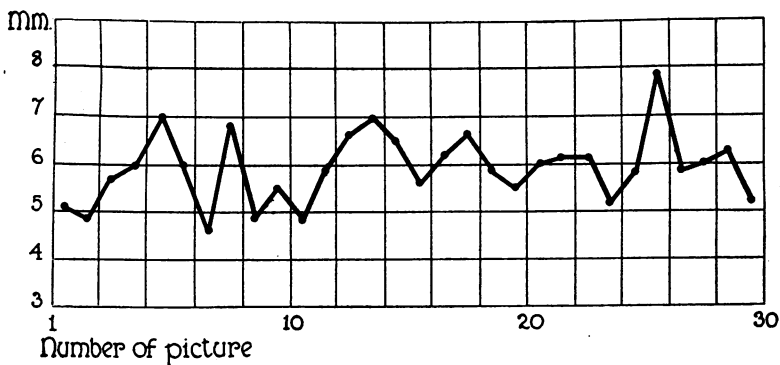


FIG. 2. THE CHANGES ARE SHOWN WHICH TAKE PLACE IN THE DIAMETER OF THE ARTERIAL LIMB OF A CAPILLARY IN A CASE OF CHRONIC MYOCARDITIS WITH ADVANCED HEART FAILURE. $\times 350$

dence of a peristaltic wave of the capillaries or of local rhythmical contractions in them. The changes in diameter took place irregularly and no rhythmicity was seen so that neither of these mechanisms appears to be the cause of their production.

Evidence of pulsation due to the heart beat. The method of recording simultaneously the capillary changes and the electrocardiogram en-

abled one to study whether any of those observed depend on pulsation on the capillary wall, due to an effect on the blood stream incident to cardiac systole. The duration of each cardiac systole could be accurately measured. If the changes were of a pulsatile nature the maximum diameter of the limbs of the capillary loops ought to occur at a constant time after the onset of each ventricular systole. All the curves have been analyzed from this point of view but the time at which the maximum diameter occurred has no relation to the onset of cardiac systole. It appears, therefore, that cardiac pulsation does not account for the changes observed.

Blood flow. The blood flow was studied by inspection over prolonged periods of time. The rate of flow was continually changing in the same capillary; different capillaries in the same subject also varied in this respect. In early cases the stream was usually rapid and resembled in every respect that seen in normal subjects. In the more advanced cases the rate of flow was slower while in those with advanced heart failure the stream was very slow and in many cases stasis was present for considerable periods of time. Marked sudden variations were often seen and gaps in the corpuscular stream were frequently present. The general appearance was similar in every respect to that seen in cases of auricular fibrillation with advanced heart failure.

Digitalis. The more advanced patients were studied both before and after thorough digitalization. Only one case derived definite clinical benefit. In this case the extent of the variations in the diameter of the limbs of the capillaries was reduced while the blood flow improved in a corresponding manner. In the other cases which were uninfluenced by digitalis there was no change observed in the capillary circulation.

DISCUSSION

The variations which took place in the calibre of the capillaries in heart disease with normal rhythm were of a similar nature to those which had been observed in normal subjects. Those cases which showed no clinical signs of heart failure did not differ in any respect from the normal, while advanced cases showed changes of the same nature but of greater magnitude. They corresponded closely to the changes which were seen in cases of auricular fibrillation with a com-

parable degree of decompensation. The extent of these variations bore no relation to the pulse rate but seemed to correspond to the state of efficiency of the circulation as judged by the clinical condition of the patient.

The blood flow in the capillaries showed a similar correspondence to the state of cardiac compensation.

No evidence was found of independent contractility of the capillaries, nor were the changes due to a pulsatile motion conveyed to the blood stream by the heart beat. Their cause is in doubt. Their nature is similar to that observed in normal cases. The possible factors involved have been discussed in an earlier paper (9). The differences which exist appear to depend on the power of the heart itself to maintain an efficient circulation.

CONCLUSION

1. The calibre of the arterial and venous limbs of the capillaries at the nail fold has been studied by means of cinematography in eight cases of heart disease with normal rhythm.

2. Changes of equal magnitude in the diameter of the arterial and venous limbs of the capillary loop take place from moment to moment. The extent of these changes varies in different capillaries in the same subject; differences are also seen between individual subjects.

3. The magnitude of the variations depends on the state of cardiac compensation and has no relation to the rate of the pulse.

4. The changes do not appear to be due to a peristaltic wave of contraction, a local rhythmical contraction of the capillaries nor to the action on the capillary wall of a pulsatory motion of the blood stream caused by the heart beat. The cause of their production is uncertain.

5. The blood flow in cases without cardiac decompensation is similar to that seen in normal subjects while in cases with cardiac decompensation the flow is slow and irregular such as was observed in cases of auricular fibrillation with a comparable degree of decompensation.

BIBLIOGRAPHY

1. Weiss, E., *Deut. Arch. f. klin. Med.*, 1916, cxix, 1. Beobachtung und mikro-photographische Darstellung der Hautkapillaren am lebenden Menschen.
Weiss, E. and Müller, O. *Münch. Med. Woch.*, 1917, lxiv, 609. Ueber Beobachtung der Hautkapillaren und ihre klinische Bedeutung.

1. Weiss, E., *Wien. Klin. Woch.*, 1918, xxxi, 41. Ueber Beobachtung der Hautkapillaren und ihre klinische Bedeutung.
2. Schur, H., *Wien. Klin. Woch.*, 1919, xxxii, 1201. Mikroskopische Hautstudien am Lebenden.
3. Jürgensen, E., *Deut. Arch. f. klin. Med.*, 1920, cxxxii, 204. Mikrokapillarbeobachtungen: Ein Beitrag zur pathologischen Physiologie der Kreislaufsystems.
4. Neumann, R., *Berl. Klin. Woch.*, 1920, lvii, 826. Kapillarstudien mittels der mikroskopischen Kapillarbeobachtungsmethode nach Müller-Weiss.
5. Secher, K., *Acta Med. Scand.*, 1922, lvi, 295. Klinische Kapillaruntersuchungen.
6. Freedlander, S. O., and Lenhart, C. H., *Arch. Int. Med.*, 1922, xxix, 12. Clinical Observations on the Capillary Circulation.
7. Hisinger-Jagerskiöld, E., *Acta Med. Scand.*, 1923, lviii, 231. Klinische Kapillarstudien bei Blutkrankheiten und Zirkulationsstörungen.
8. Crawford, J. Hamilton, and Rosenberger, H. *Jour. Clin. Invest.*, 1926, ii, 343. Studies on Human Capillaries. I. An Apparatus for Cinematographic Observation of Human Capillaries.
9. Crawford, J. Hamilton with the assistance of H. Rosenberger, *Jour. Clin. Invest.*, 1926, ii, 351. Studies on Human Capillaries. II. Observations on the Capillary Circulation in Normal Subjects.
10. Crawford, J. Hamilton, *Jour. Clin. Invest.*, 1927, iv, 307. Studies on Human Capillaries. IV. Observations on the Nature of the Capillary Pulse in Aortic Insufficiency.