OBSERVATIONS ON THE CIRCULATORY SYSTEM.

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VII.

The Ability of the Blood-vessels to withstand the Long-continued Strain caused by the Blood Pressure.

The blood flows in its channels under varying degrees of pressure. In the larger arteries the pressure may sometimes reach 200 mm. Hg; even in the capillaries (e.g., those of the foot in the upright position) it may exceed 100 mm. Hg. This pressure causes the vessel walls to be put on the stretch, and the tissue tends to cause a progressive, permanent elongation (i.e., elongation beyond the power of recoil) of its constituent elements; it is therefore evident that the elements composing vascular tissue must be peculiarly adapted to resist such a tendency, for otherwise the blood-vessels would undergo a progressive yielding, laterally and lengthwise, becoming increasingly dilated and tortuous.

Consider how readily such an organ as the bladder yields before a few mm. Hg of pressure, reaching as it may before the third day in the course of a few days. Consider, again, how a thick-walled ovarian cyst may be put on the edge of low pressure be made to expand to enormous dimensions.

Consider, further, how even bone may give way before the sustained action of quite moderate pressure; the dentist is able to move the teeth, and the nose- and mouth-chambers, they are subjected to a plus internal pressure, since in these cases the factor of pressure-absorption may come into play. If, then, dense bone yields before long-continued strain of quite moderate degree, is it not strange that the soft vascular tissues, subjected as they are to a lifelong stretching from the increase of the heart be seen to its original length? 

It should be noted that mere strength of wall—merely ability to resist rupture under a high degree of internal pressure—will not prevent the blood-vessels from steadily giving way to the long-continued pressure of the blood. It having been proved that it needs a pressure some 30 times the normal arterial pressure to rupture an artery, there is a temptation to think that the ability of a tissue-element to resist being permanently lengthened by stretching is intimately related to, if not identical with, its elasticity. A non-elastic substance (e.g., the stomach, intestines, trachea, bronchi, and gland ducts), are similarly adapted to withstand the liability ; and, indeed, it will be found that not the blood-vessels only but all the cavities and tubes of the body, the walls of which are subjected to continuous or intermittent pressure from within (e.g., the stomach, intestines, trachea, bronchi, and gland ducts), are similarly adapted to withstand the liability.

The truth of this is attested by many facts. Thus the proportion of these tissues in both arteries and veins is closely related to the amount of blood pressure they are required to sustain. Yellow elastic tissue and muscle in its contracted state are, then, peculiarly resistant to permanent lengthening by stretching, and it will be found that the proportion of these tissues in both arteries and veins is closely related to the amount of blood pressure they are required to sustain. Yellow elastic tissue and muscle in its contracted state are, then, peculiarly resistant to permanent lengthening by stretching.

Relaxed muscle being less elastic than contracted muscle is, for the reason mentioned, more apt to "give" permanently as the result of stretching than contracted muscle. The truth of this is attested by many facts. Thus the process of cardiac dilatation takes place during the period of diastole, when the muscle-fibres are in a condition of considerable relaxation; similarly, dilatation of the stomach results from the disentension of this organ when its muscle fibres are in a state of relaxation; and the absence of pyloric constriction against a gastric innery may alone lead to the condition again—what concerns us more particularly in this place—chronic hypotension of the vascular media, as we shall see, a potent factor in the production of arterial tortuosity as well as vascular disease.

Among the tissues which oppose considerable resistance to permanent lengthening by stretching dense fibrous tissue occupies a prominent place. This is shown by the behaviour of the tendons and scar tissue. Tissue of this kind is, however, more particularly endowed by virtue of its two special kinds of tissue—yellow elastic and muscle tissue. The latter, though comparatively inelastic in the non-contracted state, assumes, as we have seen, a high degree of elasticity when under contraction. Yellow elastic tissue and muscle in its contracted state are, then, peculiarly resistant to permanent lengthening by stretching, and it will be found that the proportion of these tissues in both arteries and veins is closely related to the amount of blood pressure they are required to sustain. Yellow elastic tissue and muscle in its contracted state are, then, peculiarly resistant to permanent lengthening by stretching.

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these vessels as a rule present no tortuosity, but they become tortuous in course of time, sometimes earlier, sometimes later. On the one hand, commencing tortuosity may be observed in infancy, and on the other it may be all but absent in octogenarians. There seems, indeed, to be a tendency for tortuous temporaI vessels to recover something of their pristine straightness in advanced life owing apparently to a falling of the blood pressure.

I once thought, as some probably still do, that decided tortuosity may be observed in vessels that have undergone a moderate degree of the radial arteries, indicated the existence of protracted high blood pressure; and contrariwise, that the absence of decided tortuosity in the former and of tortuosity, even moderate, in the latter was proof positive that the pressure was lower. With this view I was abandoned, however, when I found that marked temporal tortuosity and some degree—indeed, sometimes a considerable degree—of radial tortuosity may occur in subjects of habitually moderate blood pressure; and, again, that in subjects of protracted high pressure the temporaI may present very little tortuosity, while the radials may be perfectly straight. As a matter of fact, the temporal artery in adults at least may not only present extreme tortuosity in subjects of low blood pressure, but, what is even more remarkable, it may in such cases stand out prominently dilated (the condition on the side of straightness in the radial always is) by dilatation and thickening; on the right side it shows very little tortuosity, dilatation, or thickening. How can this difference be explained in such cases? Obviously not by reference to the general blood pressure. I submit that it is the special condition of the side of the vessel which has been habitually in a state of normal tonus, or possibly even of hypertonus (so that none of the coats of the vessel has been permitted to be stretched beyond a certain narrow limit), on the other side the habitual condition of the vessel has been one of hypotonus, allowing not only the muscle fibres, but all the vascular elements, to be put on the stretch. This condition of hypotonus further predisposes to tortuosity by increasing the tension in the vessel-wall, which it does in two ways—by causing a widening in the lumen of the vessel, and, to a less extent, by diminishing the local resistance to the blood flow and thus increasing the local blood pressure. It is not, therefore, surprising that protracted hypotonus of the temporal artery should lead to a permanent yielding of its walls, for not only does hypotonus allow the muscle fibres to be stretched, but the muscle fibre; not only, again, does it fall in its function of bearing off the strain of the blood pressure on the other vascular elements; but it further leads to an augmentation in vascular tension in the ways just mentioned.

As I have observed in vessels which have been diluted and tortuous as the result of long-continued hypotonus, I believe, mainly due to a hyperplasia of the connective-tissue elements resulting from the irritation set up by chronic over-stretching of them. We have seen that with normal tonus, and still more with hypotonus, the vascular strain caused by the blood pressure is largely borne off from the connective tissue of the vessel wall. With hypotonus, however, the connective tissue elements are subjected to considerable stretching, under the stimulus of which they increase and multiply.

From the foregoing it is obvious that marked temporal tortuosity (although perhaps more common in subjects of high blood pressure than in others) does not necessarily indicate high blood pressure as Recklinghausen explains it. He says that "the increase in the size of a vessel lumen depends upon the rate of the blood current," and adds that "the increase he does not tell us. The thickening in the vessel wall he attributes to the augmented vascular tension resulting from the increase in vascular lumen; for, according to a second law enunciated by him, "the growth in thickness in the vessel wall is dependent upon its tension." Proof of this he finds in the varying strength of the arterial,
capillary, and venous walls. In my view the thickening is due to the increased tension in the connective tissue elements of the vessel wall resulting hypertonicity.

Enough has now been said to render it evident that an important function of the muscular tissue with which all the arteries in the body are endowed is, by its active contraction, to prevent them from progressively yielding before the ceaselessly increasing strain being put on them. It is, therefore, no surprise to find that there is a definite relation between the amount of muscular tissue (as well as of the elastic tissue) in any given artery and the amount of blood pressure it is normally called upon to bear. Thus we find that the arteries of the lower extremities are more thickly coated with muscular tissue than are those of the upper extremities and of the head and neck, owing to the high degree of hydrostatic pressure they are required to sustain in the upright position.

By its active contraction, the muscular element of the arterial wall acts in this function of the arterial muscular media we should expect the degree of contraction of the latter to vary with the degree of blood pressure the vessel is called upon to sustain; and there can be no doubt that it does so vary. When, e.g., the horizontal position is changed for the upright, the muscular coat, not only to prevent their being sagged out by the hydrostatic blood pressure (thus obviating an undue accumulation of blood in dependent parts), but also for the purpose of preventing that progressive yielding which results in their permanent dilatation and tortuosity. Again, when, in consequence of a widespread arteriolar contraction in the systemic circuit, the blood pressure in the pre-arteriolar vessels rises, these latter tighten up in self-defence. This has been termed by the great pathologist, Dr. Von Recklinghausen, a dilatation reflex. We may observe this in granular kidney, and so long as it persists, the vessels remain straight and undilated; if in such a case we examine the radialis, e.g., we find that it is cord-like and perfectly straight. When, however, with arteriolar hypertonia the pre-arteriolelur vessels remain hypotonic the latter to undergo progressive yielding. The radials in such a case will be found to be dilated and tortuous, and the blood pressure plus.

I cannot, of course, prove that the largest arteries, such as the aorta and its main branches, tend to become hypertonic as the result of the heightened pressure brought about by generalised arteriolar constriction. I have little doubt, however, that such is the case, and that defect in this protective function may lead to injury in the vessel-wall. When, e.g., the aorta shall, or shall not, become hypertonic in granular kidney is not merely a question of whether it is atheromatous or otherwise diseased, but also of whether the muscular elements rise to the occasion and become sufficiently hypertonic to withstand the strain of the persistent plus pressure. It is the opinion that the variations in tonus manifested by the pre-arteriolar vessels (at all events in all arteries as large as, and larger than, the radial arteries) are in the main protective, and that they have comparatively little influence, either in regulating local blood flow or in varying peripheral resistance, with both of which functions the arterioles are essentially concerned. Thus, so far as concerns the blood-supply or the pre-capillary resistance in the upper extremities, it matters little whether the radial and ulnar arteries are hypertonic or hypotonic. In either case the tissues they supply can be either deluged with blood or altogether bereft of it by modifications in arteriolar tonus. I do not, of course, deny that when it is needful to bring about a maximum flow of blood to one or more parts of the body, the radial uptake of the peripheral resistance, with both of which functions the arterioles are essentially concerned. Thus, so far as concerns the blood-supply or the pre-capillary resistance in the upper extremities, it matters little whether the radial and ulnar arteries are hypertonic or hypotonic. In either case the tissues they supply can be either deluged with blood or altogether bereft of it by modifications in arteriolar tonus. I do not, of course, deny that when it is needful to bring about a maximum flow of blood to one or more parts of the body, the radial uptake of the peripheral resistance, with both of which functions the arterioles are essentially concerned.

The part played by the muscular elements in the arterial wall in preventing a progressive yielding is further shown by the fact that arterial aneurysm only occurs when the medial tissue of the entire arterial wall would very soon become aneurysmal.

(Motoring Notes)