THE HASTINGS PRIZE ESSAY, 1870.

ON DIGITALIS: ITS MODE OF ACTION AND ITS USE.*

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WE will now proceed to the consideration of each proposition in detail.

1. *Increased Arterial Distension and Tension.*—The immediate effect of increased contraction of the ventricle and more complete emptying of the chamber is, that a greater volume of blood is thrown into the aorta, and a more perfect arterial tension produced. Thus we have improvement in the whole circulation, and relief of the systemic symptoms. Cyanosis or blood-stasis is relieved by the more perfect delivery of blood, by increasing the *vis a tergo*; while the emptying of the distended veins assists in inducing a more perfect general circulation. The pulmonic circulation shares in this improvement, and thus the congestion is abated, and with it the dyspnoea. For, when there is so much extra bulk of blood within a given thoracic space, there must be less room for the reception of air on inspiration. When there is an accumulation of carbonic acid in the blood, the improved circulation brings it more rapidly into contact with the pulmonary membrane, and a more perfect interchange of carbonic acid and oxygen takes place, the blood is more thoroughly purified, and the condition of carbonic acid poisoning—the result of wear within the organism—is relieved; thus one of the most dangerous sequelæ is, for a time at least, held at bay. Relief of other consequences, as dropsy, etc., follows for the same reason. The relief thus obtained is the direct result of a larger volume of blood being thrown into the aorta; for after that the arterial recoil completes the propelling impulse. As long as the arterial coats are sound and retain their elasticity, the ventricular contraction merely produces arterial tension; the arterial recoil is the propelling power after that. When the arteries are rendered less elastic by atheroma, or endarteritis deformans, hypertrophy of the ventricle follows, and the blood is propelled by a sustained effort, very evident in a good sphygmographic tracing, and evident in the pulse at the wrist. Ordinarily, however, the arterial elasticity and recoil complete the impulse received from the ventricular contraction. The greater, then, the distension, the greater the arterial recoil. We thus come to—

2. *Increased Arterial Recoil.*—The arterial recoil, besides completing the impulse received from the ventricular contraction, has an action which is rarely sufficiently recognised. The propelling power through the coronary circulation is the arterial systole. Contrary to other arteries, the propelling power into the coronary arteries is solely the arterial recoil or systole; opening out from the sinuses of Valsalva, they run in a direction opposite to the current occasioned by the ventricular contraction. But the arterial recoil, arrested in the backward direction by the semilunar valves, fills the coronary arteries, and that, too, during the diastole, or heart's period of rest. The question of arterial tension and recoil thus bears directly on the circulation through the coronary arteries—the nutrient arteries of the heart. Thus, too, the blood-supply is secured to the muscular walls of the heart during their period of rest, and not during their activity, which would oppose an obstruction to the circulation, and which would be the case if the ventricular systole were the propelling power through the coronaries. It is thus easy to see how the blood-supply of the heart itself is more perfect, from its being associated with the arterial, rather than the ventricular, systole. Thus increased arterial recoil leads directly to—

3. *Increased or Improved Coronary Circulation.*—It being thus seen how the coronary circulation takes its rise in the arterial recoil, it is easy to see how an improvement in the arterial distension leads to a more perfect circulation through the coronary arteries, and thus to a more perfect supply of blood to the heart's structure, and a freer supply of nutrition to it. The condition of the muscular structures is intimately associated with their blood-supply. Whenever the blood-supply is defective, the muscles deteriorate, and their efficiency is interfered with. However rich the blood may be, and supplied with nutritive material by perfect digestion, if the circulation through any part be interfered with, that part suffers, and does not benefit by the abundance

of nutritive material in the blood. If the blood be impoverished, then, of course, the nutrition of every part is interfered with, but still more so in the part also labouring under obstructed local flow. The arterial recoil has much to do with the general circulation, no doubt, and the unsustained pulse of unfilled—that is, undistended—arteries is well known; the sphygmograph shows a rapid fall after the rise of the systole. This unfilled condition affects all parts; but the heart-structure, through which the coronaries run, is most affected. Their impulse being solely that of arterial recoil, the want of it is a serious drawback to the coronary circulation; while, at the same time, the incessant action of the heart demands a very perfect nutrition to preserve its integrity. Thus, then, improved action of the ventricle leads to increased arterial tension, and through that, by its increasing recoil and improved coronary circulation, to more perfect self-nutrition. Thus hypertrophy tends to perpetuate itself, though to an inferior extent, where there is aortic regurgitation or atheroma; that is, loss of arterial elasticity. In these conditions the recoil no longer fills the coronaries, and a deficient flow sooner or later impairs the structural integrity of the heart. When, however, the dilated or distended heart, accompanied by a rapid, feeble pulse, evidencing a diminished arterial tension, is just pumping a little off the top of the contained blood, there is an inherent probability of tissue-degeneration following at no distant date. The feeble impulse and lessened recoil do not fill the coronary arteries; while the rapidity of the contractions, by infringing on the heart's period of rest between the beats, does not afford the pause during which the coronary arteries supply the heart-walls with nutrition. Thus we see how the improved ventricular contraction leads directly to a better tissue-nutrition; that is, to a consequent hypertrophy. Thus a more perfect action of the ventricle leads to a more perfect nutrition of itself by a special provision, as well as by the general law of increased action leading to increased nutrition, which holds good in all parts of the body equally.

4. *Increased Nutrition of the Heart.*—The improvement in the circulation by supplying more nutritive material to the muscular structure of the heart, and, at the same time, a more perfect removal of waste material, furnishes one factor in the question; the increased systole and lengthened diastole furnish a prolonged period of rest—another factor; and the increased muscular activity, a greater demand for nutrition. There are thus aggregated all the circumstances favourable to improved nutrition.

5. *Compensating Hypertrophy.*—This increased nutrition leads in a direct manner to hypertrophy. The well known instances of the arm of the blacksmith and the leg of a ballet-dancer demonstrate the growth which accompanies activity with a good supply of nutritive material. For, without the nutrition, the activity leads to degeneration, as seen in the muscles of the top-sawyer mentioned in Chambers's *Clinical Lectures*. But, with the improved circulation, all parts are improved; there is better appetite, and more perfect digestion. The relief of the systemic symptoms has set every organ into more perfect action. A more perfect elaboration furnishes more nutrition to the blood, now more rapidly circulated through every organ. From a widening circle of troubles, there is now a widening circle of improvement felt everywhere. The muscular activity, causing a greater demand for formative material, finds it provided by the very action that now calls for it, and tissue-activity leads directly to improved tissue-growth. It matters little whether this be by reduplication of fibres, or increase in length and strength; sufficient that it exists. Thus the muscular walls are better enabled either to resist the distending action of the blood forced in under greater pressure, or to overcome an obstruction to the flow of blood forward. Hypertrophy of muscular tissue is the restoration of the balance, as the result of natural processes. Compensatory hypertrophy frequently enables serious lesion to be borne without any great constitutional embarrassment. It is the way in which the system again strikes the balance in well-nourished individuals; and, as a natural process, it is only too desirable to imitate it and favour it. Compensatory hypertrophy, again, restores a balance between the opposing forces of propulsion and obstruction. When hypertrophy is sufficiently pronounced, an almost perfect compensation may be said to exist. Niemeyer states that a huntsman in Griefswald, who suffered from "extensive stenosis and aortic insufficiency, and immense excentric hypertrophy of the left ventricle, performed all the manœuvres and forced marches of the army without difficulty" (vol. i, fol. 347). Compensatory hypertrophy is Nature's mode of repairing injuries to the heart's integrity; and in treatment I have striven to make it mine, and certainly not without success. By a proper recognition of this principle, and of the means by which it may be attained, a much more effective treatment of heart-lesions may be resorted to than is currently believed. *Experto crede.*

6. *Considerations on Atheroma and Fatty Degeneration.*—The question of atheroma, however, materially interferes with these changes at

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every step. It may be desirable, and not un instructive, to follow for a while this interference. Atheroma is essentially a parenchymatous inflammation of the inner arterial tissues, and may either exist in patches or be more general, leading to dilatation of the arteries, and loss of elasticity. When the arterial elasticity is impaired, the artery distended by the ventricular systole is unable to recover itself. It thus remains more and more distended, and when possible, elongated—*i.e.*, tortuous. This impaired elasticity then lessens the recoil; the distension and elongation of the arteries interfere with the recoil, and instead of perfect recoil, the artery remains permanently enlarged. This change goes on gradually, incessantly aggravated by exertion and all calls on the heart for increased action. The arteries become elongated and distended, from the aorta to the tortuous temporal artery; they are increased in length and breadth; they become, too, more brittle and more easily ruptured by strain. Here, now, we see a wonderful instance of conservative change, tending directly to prolong the existence of the organism. The diseased arteries recoil less perfectly, and thus the coronary circulation becomes involved and its circulation diminished, and thus impaired nutrition of the heart; and from that, again, lessened and impaired activity, and thus diminished risk of the heart rupturing the diseased and friable arteries. Thus we see that not only is fatty degeneration a preservative lesion, as Sir William Jenner showed at Leeds, but that that very change which is preservative in its action, is entailed by the diseased condition of the arteries, which the very want of that lesion would endanger. Thus the changes go on, hand in hand; the more diseased, brittle, and non-elastic the arteries, the less their power of recoil, and thus impaired structural integrity of the heart and impaired contractile power. The diseased arteries thus fortunately lead to the very muscular change imperatively necessary in order to prevent the heart from rupturing them. Where the atheroma is general, there is a stronger probability of fatty degeneration following, and thus this condition is more favourable to life than when the atheroma is in patches. Where the atheroma is deposited in ring-like, annular patches, encircling the aorta at the branching off of some smaller artery—its favourite seat—it is more fraught with danger. The hypertrophy consequent on the obstruction to the flow, and increased tension resulting from the obstruction, does not so soon undergo preservative degeneration, as the sound parts preserve their elasticity and recoil fairly. Thus the obstruction of the isolated masses, especially if annular, keeps up the hypertrophy by increasing the tension behind them and the results of increased arterial tension, and thus endangers the patient's existence by the increased risk of some degenerate mass giving way. In these conditions, increased ventricular action could only render them more and more dangerous; the greater contraction and distension would try still farther the degenerate vessels, and could only slightly improve the coronary circulation, and thus only to a small extent diminish the risk of arrest of the heart's action, while it would certainly greatly enhance the more imminent risk of arterial rupture. If ever hypertrophy is to be regarded as otherwise than an unalloyed good, it is in these conditions. Certainly any attempt to secure it artificially in the manner described, would be detrimental to the patient's real interests; as the attempt to extenuate one danger would greatly enhance the hazard of another.

Use in Hypertrophy.—In hypertrophy of the heart, perhaps, the action of digitalis was first, and is perhaps most readily, observed. For, hypertrophy being essentially compensatory, balance between the blood to be driven and the power to drive it is being already re-established by the efforts of nature. Of course, the effect of a drug whose action is to drive the ventricle into contraction, would be most quickly and evidently apparent in this condition, where a restoration of the balance is being wrought out, than in dilatation where no such compensatory change is being attempted. In hypertrophy, no great amount of the drug would disturb the balance in the opposite direction, and then the symptoms of digitalis poisoning—*i.e.*, of the drug driving the ventricle into an abnormal state of contraction—would be readily produced. This condition was thought to be due to the drug producing a marked sedative effect on the heart, and was considered the strongest proof of its sedative action. The condition of collapse is due to a defective arterial distension, and if that is brought about by a small bulk of blood being thrown into the aorta at each ventricular systole, it matters not whether it be due to a distended ventricle just pumping a little off the top of the contained blood (as was thought the case), or to its being in a state of unnatural contraction, and only admitting partial distension on the auricular contraction. Of course, in dilatation much larger doses are not only tolerated, but required; and from there being no attempt at compensating hypertrophy to restore the disturbed balance, a greater stimulus to contraction is necessary to produce the desired results. It is thus comparatively easy to understand here how the early observers, who perceived such marked results follow the use of small doses

of digitalis in hypertrophy, conceived the idea of its being a sedative, and dreaded its use in dilatation; in fact, regarding the use of large doses in dilatation as open heresy. A knowledge of its real action, however, explains in a satisfactory manner the apparent anomaly, and explains its effects in each condition; its almost magical effect in hypertrophy in small doses; its tolerance in large doses in dilatation. Thus we see how digitalis is tolerated in large doses for months—nay, years—in cases of confirmed dilatation, where its action, or that of some substance of similar property, is necessary to the preservation of the organism. In dilatation, where the system is confessedly unequal to the establishment of compensatory muscular hypertrophy—of a balance again being struck between the forces of obstruction and the power to overcome it—the use of a drug whose action is to throw the ventricle into a state of tonic contraction is readily understood as being of the greatest service; and this also explains how its use in large and continued doses is not only not productive of symptoms of poisoning—*i.e.*, of ventricular spasm, which was once imagined to be due to an accumulation of the drug in the system in some mysterious inexplicable manner—but is even necessary to the continuance of life. Without it, or some similarly acting drug, dilatation must become only more and more extensive, and hand in hand with that extension must be an increasing inability on the part of the heart to recover itself; hence still more enfeebled circulation, blood-stasis and its consequences, until the widening vicious circle ends in somatic death. In hypertrophy, where the system is equal to an attempt at restoring the disturbed balance by increasing the muscular driving power, and where occasional palpitation alone reveals the remaining inequality, the use of digitalis soon enables the sympathetic ganglia and other muscular servants to get over the difficulty, and tides on the system, until a more perfect histogenesis has again struck a balance, and a permanent equilibrium is established. In this condition of compensatory growth and power, the continuance of the drug would soon be fraught with a new danger from the ventricular contraction becoming excessive. This, I believe, is the true explanation of an apparently opposite action of digitalis, which has long divided the ranks of medicine. It is not that hypertrophy is any bar to its administration, only it is required in less doses. As long as a heart is equal to its work, neither patient nor physician would interfere; but when its inability is revealed by palpitation and the other evidences of over-taxation, hypertrophy does not forbid the use of digitalis, but it is only required in small quantities, as by these small quantities the desired results can be obtained. But it must not be given on any idea of its tranquillising action being in its nature allied to that of a narcotic or a sedative; it is by enabling the heart to contract without laboured effort that it calms excitement. Niemeyer states: "Digitalis in pure uncomplicated hypertrophy is unsuitable. As has been brilliantly demonstrated by Reich, the results of experiments with this medicine on dogs stand in glaring contradiction to the conclusions drawn from experience at the bedside. (On the Employment of Digitalis in Disease of the Heart. Inaugural address under Professor Niemeyer, Tübingen, 1864.) The action of digitalis, under the use of which innumerable cases of disease of the heart, cyanosis, dropsy, hepatic engorgement, and suppression of urine have been made to subside, is not to lower the centrifugal pressure of the arteries, but rather to increase it. Its use is indicated in diseases in which the action of the heart is weakened, but never in cases where it is augmented" (vol. i, fol. 315) *Text-Book of Practical Medicine*.

In Valvular Disease.—In valvular disease, no effect must be expected from digitalis, except so far as it acts on the muscular walls. It happens, however, that alteration in the muscular walls is compensatory; in injured valves so much so, that life may be maintained for years, and sometimes with a fair share of activity, in the presence of serious valvular mischief. Dr. Chambers (*Clinical Lectures*) states: "The existence or non-existence of valvular disease lies not so much in the injury it inflicts itself, as in the likelihood of the induction of other lesions of the heart. If the muscular structure remain healthy, injured valves do not appear capable of causing death." In obstructive disease this is readily comprehended, for it can be reduced to simply this. It is necessary for the wants of the system that so much blood be driven through a certain orifice in a given time; and if that orifice be narrowed or otherwise partially occluded, for this to be accomplished it is imperative that the driving power be increased. In fact, hypertrophy is compensatory, and enables this to be done; and where there is this hypertrophy, the patient himself may not be conscious that any morbid change has gone on in him. In fact, between hypertrophy and dilatation again does the balance rock, and with it the prognosis; in hypertrophy, as long as it can be maintained, the patient's chance of life is a good one; in dilatation the aspect is clouded, and an artificial hypertrophy must be attempted. Artificial hypertrophy is no therapeutic fiction, and can be produced by more or less time and perseverance, in

a great many cases, by administering agents which produce a better ventricular contraction, and a system of nutritive support; for the law of increased action being followed by increased tissue nutrition in normal texture is unalterable, if healthy blood be furnished. The good effect of change in the muscular walls in regurgitant valvular disease is not at first sight so perceptible as in regurgitant mitral, for instance, where the question is far from an uncomplicated one. No observer of much experience will have any difficulty in recalling numerous instances of mitral regurgitation with hypertrophy, or dilatation, or both, of the left ventricle, and where the ventricular change is consequent. Let us see how, where no drug has been administered, the system's power of repair has set up compensatory changes. Valves, it must be remembered, are not found in hearts of the lowest grade, and are only belonging to complicated and involved hearts; the primitive heart is a mere "pulsatile sac", a thickened and dilated section of a tube. So, when the valves are injured, the heart is reduced to a lower type; that is, the muscular walls no longer get that aid from the valves to which they have been accustomed, and consequently augmented work and increased growth are entailed. In fact, the muscular structure is no longer aided by this beautiful mechanical contrivance, and so change in itself is necessitated. The blood is no longer thrown forward into the aorta at each ventricular systole completely, but a portion regurgitates through the imperfect auriculo-ventricular valve, and thus overloads the venous system behind. The pulmonic system and the right ventricle undergo compensatory changes of dilatation with thickening; the power of the pulmonic system, in fact, is generally increased; the blood pours into the left ventricle on its diastole, under greater pressure, and thus distension of it follows, with hypertrophy or dilatation as its usual concomitants; the usual question of restorative power of the system deciding whether. The consequence of this change is one little to be expected by any one who has not given the subject of compensatory changes its proper consideration. It is this; that, in spite of the regurgitation of a considerable amount of blood, it (the ventricle) remains capable of filling the aorta (Niemeyer). That it does so with more or less success is evidenced by the irregularity of the pulse—not irregularity in time, but irregularity in volume, sometimes nearly the whole amount of blood passing forward, and then again a great portion passing backwards. But to achieve this change in the left ventricle, increase of growth behind the lesion is unavoidably necessary; without the opposition of the blood in the pulmonic system, and the hypertrophied right ventricle, this would be unattainable. Thus we see that muscular change is compensatory in regurgitant disease behind, as well as obstructive disease before.

Sir Dominic Corrigan considered the advantage of administering digitalis (and the fact of relief being afforded by it as unquestionable, however defective the explanation) to lie in its rendering ventricular action slow. Thus in aortic obstruction it allowed the ventricle more time to perfectly empty itself into the aorta; that is, compensation took place by more time being allowed for the passing of the blood into the aorta through the narrowed orifice. The objection to this theory lies here: there is a diastole as well as a systole, and a prolonged systole must necessitate a shortened diastole, or no compensatory good can accrue. For the ventricle must be filled before systole, and that requires time; so that if the advantage lies in the retardation, it is difficult to see how it is any advantage. There must, on this explanation, be so many fewer contractions in the minute, and the wants of the system would be as unsupplied as ever. It is not, and cannot be, a question of time, but of power. What comes of the hypertrophy which occurs in obstruction? To what is it compensatory on the theory of time? After the ventricular action has been rendered slow, the hypertrophy ought to pass away, as it does in a parturient woman. Whether it does so or not, I cannot tell, as I have not found the pulse made slow in aortic obstruction in my experience. So in mitral obstruction it was supposed to be beneficial by allowing the auricle more time to empty itself into the ventricle. But, unfortunately, the same objection meets us here, and, further, the ventricle is nearly full when the auricle contracts. It is the distension of the auricle which evokes contraction; its contraction produces distension of the ventricle, which distension then provokes ventricular contraction, but the ventricle is nearly full when the auricle contracts. In mitral regurgitation, the retardation could have no good effect. The question is not one of time, but of power. In obstructive disease, a simple hypertrophy enables the ventricles to throw an equal quantity of blood through a narrowed space in a given time. In order that an equal quantity of blood may be driven through a narrowed orifice in an equal time, we must have increased power. No other arrangement could possibly achieve the result. In regurgitant disease, the question is not nearly so simple; and in order to comprehend exactly how digitalis can give relief in mitral regurgitation, a digression for a little time is absolutely necessary, so that we may review the changes which the

normal conservative power of the system, unaided by art, can produce; and it is in imitating or assisting these changes that we can alone hope to be of service. The effect, then, of mitral insufficiency is regurgitation into the pulmonary veins. The lung-space is unduly filled with blood, and therefore has not sufficient space for air; hence the dyspnoea commonly found as a symptom of this lesion. The circulation is impeded, and the blood is imperfectly aerated, and flows less readily into the pulmonary veins from the capillaries.* Thus there is further tendency to pulmonary engorgement and obstructed flow. This impediment to the flow of blood from the right ventricle entails in it changes. The right ventricle becomes dilated and hypertrophied. First there is dilatation, and then hypertrophy comes to the rescue. The overloading of the pulmonic circulation leads directly to changes in the muscular walls, and again the battle of life or death rests on the power of self-growth in the involuntary muscular fibre. If the yielding lead to degeneration, sudden death is the probable result at no distant period; if to a lesion in the tricuspid, then the stress falls back on the veins, and dropsy results, with all its train of troubles. The temporary effusion through the walls of the veins or venous capillaries often gives great relief to the patient; in fact, the blood, overlaid with water, is relieved of part of its burden, the overcharged circulatory system is somewhat eased, and the improvement of all the systemic symptoms is consequent. But it has added another trouble in the future, and the passing relief is embittered by the reflection that it is a mere bill of accommodation that will soon be due again. The relief to the distended venous and pulmonic systems sometimes admits of their recovering themselves to some extent, but this is unfortunately only a rare occurrence. Dropsy, that is effusion from distended capillaries, is also taking place into the pulmonary tissues, and pulmonary oedema increases the patient's woes; blood even may be effused when the distension is great, and there is no more alarming consequential symptom of mitral regurgitation than hæmoptysis. The stress on the systemic veins directly affects the systemic circulation, and increases the stress on the left ventricle; increased difficulty of flow is superadded, and the pulmonary engorgement is redoubled. In addition, the liver is gorged, and the spleen distended; the kidneys are in a condition of asthenic congestion, and the pressure on the glomeruli is lessened; thus the flow of water by dialysis is interfered with, and the bulk of urine radically lessened; and thus we have an extended circle of mischiefs aiding and abetting each other, acting and reacting till it becomes difficult to ascertain the starting point. This is no exaggerated or even highly coloured picture of the condition of the patient suffering from mitral insufficiency and its consequences. But against this train of troubles must be set the power of hypertrophy in the right ventricle. If there be sufficient compensatory change, then all this may be arrested for a long period of time. Increased activity of the right ventricle gives relief to the general symptoms. The blood pouring into the left ventricle under greater pressure, and its reflux being opposed by a greater *vis a tergo*, more blood is thrown into the aorta, and thus better aortic distension follows the muscular activity as a necessary consequence. Thus the action of digitalis on the right ventricle is of the utmost importance, while its effects on the capillaries aid in sustaining the increased pressure on the pulmonic circulation. By its use, we aid that natural thickening and increase of substance which the system spontaneously sets on foot on its balance being disturbed. In some conditions, aid is unnecessary for years, or may only be required during some debilitating action, but it must never be withheld when a trying affection like bronchitis is testing to the utmost the patient's power of resistance. In other cases where the natural efforts are visibly unequal to the demand, and the struggle is being abandoned, the aid we can furnish may be less effective, and the restoration of balance more imperfect; still it is worth the trial, and tends to prolong the existence of the organism. We must never forget that, in regurgitation through the mitral valve, the condition of the right ventricle and its allies is the only hope of the physician. It is, then, to the action of the right ventricle that we must look for assistance when trouble is due to the mitral insufficiency; and it is by augmenting the contractile action of the ventricular fibres, and its effect on the capillaries by opposing their distension, that digitalis can be useful in mitral disease; for the troubles of mitral obstruction are those of mitral regurgitation. It is to the loss of compensatory action, or, rather, the inefficiency of it, that we must attribute the want of success in our treatment of tricuspid regurgitation. The increased action of the right ventricle is not lost over the short length of the pulmonic circulation, while the increased action of the left ventricle is lost over the length of the systemic circulation, and therefore exercises no useful effect in opposing the regurgitation of the blood in tricuspid insufficiency.

[To be continued.]

* The question of the readier flow of blood containing oxygen is not one to be entertained here.