

great and immediate, and there were no unpleasant symptoms whatever from the operation. As the patient happens to be in town, I have asked him, with the kind consent of Dr. Cockle, to attend here in order that any gentleman who wishes to examine him may satisfy himself from the man's own statement of the reality of the relief which the operation produced. He can now walk fourteen miles in one day, and feels perfectly well. The left side of the chest is quite flat. The tumour is felt pulsating in the episternal notch, and the right thoracic parietes bulge somewhat forwards, but the disease is plainly receding. The patient was a man aged forty-eight, a farm labourer from Cambridge-shire, who came under Dr. Cockle's care in January, 1872. He had experienced pain, for four or five years, in the right side of the head, neck, shoulder, and chest, attributed to rheumatism. In April, 1871, he noticed a pulsating swelling in the hollow of his neck, and was in Adden-brooke's Hospital for two months without relief. After Christmas, 1871, he was compelled to give up work, from the increasing pain in the shoulder and neck. He presented marked symptoms of aneurism of the ascending and transverse portions of the arch of the aorta. There was displacement of the right sterno-clavicular articulation, with projection of the right and upper portion of the sternum; and the episternal notch was filled by a pulsating swelling. There was a strongly heaving and expansile impulse over the whole of the swelling, and marked dullness on percussion existed over the whole area of the tumour. No bruit could be heard, but a double concussion-shock was felt. The respiratory murmur was feeble or absent over the upper portion of the right lung. The heart-sounds were dull and muffled, but without appreciable murmur. There was no cough or difficulty of deglutition. The left radial pulse was decidedly feebler than the right; and the left pupil was much dilated, and the left eye congested. On exertion he complained of shortness of breath, palpitation, and pain. Mr. Heath tied the left carotid artery above the omo-hyoid on February 26th, 1872. Carbolic catgut was used for the ligature, and the wound was covered with cotton-wool. No constitutional disturbance followed. Within forty-eight hours the patient could lie and sleep on his right side, which he had been unable to do before. The left pupil became natural, and the congestion of the eye disappeared. On the eighth day, when the dressings were removed for the first time, the wound was found completely healed by the first intention. Since the operation, the condition of the patient has in every way improved, the chest having become flatter, and the heaving impulse greatly diminished. He was free from all pain or inconvenience.

Our table concludes with two cases in which the sub-clavian artery has been tied in its third part for innominate aneurism. The first is the well-known case of Mrs. Denmark, operated on by Wardrop. The patient had very clear symptoms of innominate aneurism, and was suffering from most distressing feelings of impending suffocation. The pulse in the branches of the right carotid was imperceptible, and it was thought that there was no pulsation in the trunk of that artery, though on this the report is less positive. The carotid being, therefore, taken to be obstructed, Mr. Wardrop thought it well to tie the right subclavian in its third part on July 6th, 1827. "There was an immediate relief in her breathing, which now became free and tranquil, and this change was more striking as during the preceding twenty-four hours she had suffered an unusual degree of suffocating dyspnoea.....The peculiar sensations which she complained of in her head were also removed." The pulsation of the tumour was also thought to be diminished, though its size was not. On the ninth day a pulsation became perceptible in the carotid and temporal arteries, which Wardrop referred with great probability to a diminution of the size of the tumour, and consequent liberation of that vessel from pressure. The ligature came away on the twenty-second day, by which time the tumour was "greatly reduced in size." In the sequel she remained for some time with hardly a trace of the former disease, inasmuch that a surgeon who saw her at the end of August declared that unless he had previously been acquainted with the nature of the case he should not have known that any aneurism existed. At the end of the year she suffered severely from bronchitis, and was treated on the strongly antiphlogistic plan. In August, 1828, Mr. Wardrop makes the following note on this head: "It is important to observe that from the com-

mencement of my attendance on this patient she has now been bled above fifty times, to an extent at each operation seldom less than a pint of blood, and frequently to nearly double that quantity. Since the ligature of the artery she has been restricted to about an ounce of solid meat daily and twelve ounces of fluid. Besides these, however, she has frequently taken a very small quantity of bread-and-butter, and occasionally a little fruit. No tumour was now perceptible in the situation of the aneurism, but a hardness was perceived there from its condensation. She had had transient oedema of the feet, but this had subsided, and she takes exercise in the open air daily." This note was made on Sept. 9th, 1828. The patient survived till Sept. 13th, 1829, when she died of dropsy, and previous to her death the aneurism had enlarged above the sternum and up the root of the right carotid artery. Wardrop proposed to tie the right carotid, but was dissuaded, apparently, by some consultants, who thought the diagnosis wrong. However, on post-mortem examination, the tumour turned out to be an innominate aneurism. "The clavicular and tracheal portions of the sac were filled with firm coagulum, the cavity of the aneurism being chiefly limited to the division between the sternal and tracheal portions, and was about the size of a walnut. The layers of the coagulum were remarkably firm, and of a pale colour, being of a softer consistence and darker colour as they approached the boundaries of the aneurismal cavity." The aorta was healthy.

As far as this case goes there seems no possibility of denying that the patient derived benefit from the operation, though the possible effect of the rigid depletion before and after the operation must not be left out of sight. It is greatly to be regretted that the carotid was not tied, for the post-mortem examination seems to have proved that the subclavian portion of the sac was obliterated, and if she had survived the ligature of the carotid, there would have been a good prospect of the permanent cure of the aneurism as in Mr. Fearn's case. It is also much to be regretted that Mr. Wardrop did not fulfil the intention which he expressed in his report of this case, of presenting this very valuable preparation to the museum of this College.

The only other case in which the subclavian has been tied on the distal side of an innominate aneurism is that by Broca, of which full details are given in the "System of Surgery," and of which it will be sufficient to say that the benefit from the operation was well marked, and that the patient's death was produced by a disease which seems to have been quite unconnected with the aneurism.

There is a case on record (by Laugier*), in which he tied the axillary for the cure of innominate aneurism; but this is not an example which anyone, I think, would now follow. The case is one of great interest in this respect that the carotid artery was obliterated, and the subclavian healthy. The patient died from cough and dyspnoea, and after death extensive disease of the vertebræ was found. As far as the account of the tumour enables us to judge, it is very possible that a ligature placed on the subclavian at an earlier period, before the vertebræ were implicated, might have been successful.

OBSERVATIONS ON THE FOUR CHIEF ORIFICES OF THE HEART.

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In a paper which I had the honour of reading before the Royal Society in the early part of 1870, I attempted to establish the existence of a law which determines the relative magnitude of the areas of the four chief openings of the heart, and I also sought to show the reasons why the orifices differed from each other in size. I took as the basis of my calculations the facts given by Drs. Peacock Reid, and others, and I assumed—1st, that the four openings during the time the blood traverses them are circular in form; and 2nd, that the area of each orifice is unchanged—constant—during systole and diastole. I propose

* THE LANCET, 1835, vol. i., p. 891.

in this communication to show that these assumptions were correct.

1st. All anatomical writers agree in describing the orifices of the aorta and pulmonary artery to be circular in circumference. I have, therefore, only to prove that the tricuspid and mitral apertures are also circular, although stated in anatomical works to be elliptic in form. And in the first place, I may recall the fact that all the canals of the body and all the outlets through which fluid has to pass are (with a few exceptions) circular in form, for the obvious reason that the *largest quantity* of fluid can pass with the *least amount* of friction through a circular opening, and therefore with the least expenditure of power on the part of the organ propelling or expelling the fluid. If, for instance, we compare the perimeters of a square, ellipse, and circle, each of which contains an area of one square inch, we shall find that they are—4, 3.85, and 3.54 inches respectively; the ellipse being taken in this case for the sake of example, as having its long axis double the length of the short axis, or as 1.6 to .8 inch. An elliptic mitral opening (on the above supposition of the length of the axes) containing one square inch would have a perimeter of .31, or nearly one-third of an inch longer than the perimeter of a mitral opening containing exactly the same area, but of a circular form. The openings of the two different forms would be of exactly the same size in area, but the circumferences bounding these equal areas would be very different in length. The elliptic would evidently expose a much larger frictional surface, and be therefore less favourable for the transit of blood than an opening of an exactly circular form enclosing the same area within its circumference. It would be interesting to discover why the longitudinal and straight sinuses in the cranium have a triangular form. It is clear that the arrangement is not merely for the purpose of packing, for we find that the small veins which empty themselves into the longitudinal sinus enter that channel at an angle, and in a direction *opposed* to the current which flows through it, showing, as it were, that great velocity is not required in the stream of the sinus. The aortic and pulmonic apertures are admitted, as I have already stated, on all hands to be circular in form. It may be, therefore, fairly asked why Nature, which economises force in all parts of the body, should adopt *oval* apertures for the admission, and *circular* openings for the exit, of the blood of the ventricles, especially as the incoming tricuspid and mitral currents possess small velocities and momenta, and require every favourable condition possible to secure their reception into their respective ventricles during the period of diastole.

Again, whatever may be the forms of these orifices as observed post mortem, when the heart is lax and empty, there must be, I believe, every probability that volumes of blood which traverse them *during life*, and exert centrifugal pressure on their circumferences, will inevitably tend to throw the *effective* openings into a circular shape. That such is the case is well seen in Dr. Pettigrew's specimen, marked 929 B, in the museum of the Royal College of Surgeons. The chambers of the heart in this specimen have been filled with fluid plaster-of-Paris, which, in hardening, has preserved the circular form of the orifices. Specimen 928 C in the same museum clearly exhibits the naturally circular openings of the tricuspid and mitral orifices in the heart of the Bison Europæus. The walls of the apertures are so thick and firm that they preserve their circular shape post mortem.

If we stuff a sheep's or bullock's heart with cotton and boil it for many hours, and detach—as we can most readily—the auricles from the ventricles, we shall find in this rude experiment the apertures to be very nearly circular in shape.

Lastly, in employing the spherical balls devised by Dr. Peacock for the measurement of the orifices, the apertures are found to be well fitted by them.

These considerations will, I think, be sufficient to establish the truth of my statement that the tricuspid and mitral orifices when in function are *circular* in form.

2nd. I will now proceed to the reasons which show that the areas of the orifices are constant—that they do not alter in superficialities during the systole or diastole of the ventricles.

(1) The rings which surround the auriculo-ventricular openings are formed of white fibro-tendinous tissue.

Being naturally inelastic, they are consequently unaltered in their perimeter by any normal eccentric pressure to which they are exposed by the passage through them of the auriculo-ventricular volumes of blood. In my former paper on this subject I have shown that the force with which these in-coming volumes enter the ventricles is small; and it is evident, therefore, why the tendinous boundaries of the auriculo-ventricular openings are feebly developed.

(2) The muscular fibres around these orifices are in no way found to be arranged in a circular form, and cannot possibly, therefore, act in the manner of a sphincter to close the openings. The fibres which constitute the walls of the ventricles are formed of seven strata, three of which are external and oblique, one central and transverse, and three internal and oblique. The first and seventh strata are alone inserted into the auriculo-ventricular rings, and converge in a direction almost at right angles to their planes, while the inner and subjacent strata have no connexion with or insertion into them, but are continuous beneath them. The masterly dissections of Dr. Pettigrew establish the truth of this description. It is clear, therefore, from this arrangement of the fibres, that the systolic contraction of the ventricles can have neither power nor influence to diminish the superficial areas of the tricuspid and mitral apertures.

(3) The muscular walls of the auricles, according to an able paper by Mr. Savory, of St. Bartholomew's Hospital, are found to terminate by two attachments. The larger and outer portion (the looped fibres of Quain and Sharpey) is closely inserted into the fibrous auriculo-ventricular ring, while the inner and thinner portion can be traced between the surfaces of the valves, terminating more or less abruptly by attachment to the tendinous tissue. The former offers no arrangement of fibres capable of contracting or in any way altering the capacity of the inlets, and the latter fibres are probably of use, as suggested by Valentin, to assist in raising the tricuspid and mitral curtains in ventricular diastole, in order that the blood may freely pass behind them and close them by recoil pressure.

It follows, therefore, that neither on the ventricular nor the auricular side is there any muscular arrangement existing capable of affecting the areas of the auriculo-ventricular apertures. In fact, the existence of valvular curtains would, I think, lead one, *a priori*, to expect that they alone are requisite and sufficient to close the apertures. *Where sphincter muscles are found, valves are absent.* We find no valves at the pylorus, anus, and orifice of the bladder in man, and the right auriculo-ventricular orifice in birds, which is *entirely* muscular in structure, exhibits no trace of a curtain.

I propose at some future time to enter into the consideration of the probable reasons why the heart of the bird differs in the shape of its right auriculo-ventricular orifice from that of the mammal. If the tricuspid and mitral orifices could be contracted by muscular action and closed, as the neck of the bladder is, by a sphincter, no valvular curtains would be required. The two forms of arrangement for closure are incompatible with one another.

Again, looking at the result, it is manifest that auricular action, if capable of diminishing the area of the orifice, would only tend to impede the flow of the blood from the auricle to the ventricle, and thereby oppose the attainment of the very object which it has to accomplish. And it is equally clear that any contraction of the area of the orifice by ventricular systole would not assist in the expulsion of the ventricular contents, inasmuch as the curtains are *inelastic*, and cannot diminish in superficial area under any effort of the papillary muscles, which regulate their position and tension. The obliteration of the ventricular chamber is effected only by the contraction of its muscular walls, during which process the auriculo-ventricular curtains are drawn down by the papillary muscles in the shape of a cone, which in its gradual descent becomes filled with blood from the auricle. The pressure on the ventricular surface of the cone continues, of course, much greater than the pressure of the blood contained in the cone, until the end of the systole, when it becomes zero, and allows the constituent portions of the cone to separate from each other under the pressure of its fluid contents; and thus is the onward current of blood favoured from one chamber to the other, and a *sudden shock* to the flow into the auricle prevented during the contraction of the ventricle. The *persistent*

opening of the auriculo-ventricular orifice during the descent of the valve, so well described by Pettigrew, forms evidently an important part of the arrangement.

There is therefore, I think, great reason for believing that the areas of the tricuspid and mitral openings are as unaffected in systole and diastole as are the areas of the aortic and pulmonic apertures. The rings which surround the latter are very strong, and capable of resisting the pressure of the volumes of blood which pass through them in systole; and unless the orifices maintained their constant areas, their valves, which are *inextensible*, would be unable at all times to adapt themselves to the openings which they have rigorously to close. The same line of argument is applicable to the auriculo-ventricular apertures and their curtains. The respective areas of these openings must be constant, in order that the inextensible valves belonging to them may be able to adapt themselves at all times to them.

As an additional illustration in proof of the constancy of the areas I may refer to some recent experiments made by Drs. Sibson and Broadbent on the living dog. In fasc. vii. of the "Medical Anatomy" Dr. Sibson says:—"When I observed the heart acting vigorously under water, after being cut out, it seemed to me that the circumference of the shut valve (mitral) did not lessen with the diminution of the ventricle towards the end of systole. It would appear that the pressure of the blood, by filling the sacculi on the under-surface, unfurls, flattens out, and enlarges the valve, so as to maintain it almost of full size to the end of systole."

If, then, it be true that all the chief orifices of the heart are circular in form when in action, and that their respective areas are constant during systole and diastole, certain objections which have been raised to the truth of the statements made in my former paper are removed, and the correctness of the formula which I have discovered—namely,

$$\frac{\text{Area of tricuspid}}{\text{Area of mitral}} = \frac{\text{Area of pulmonic}}{\text{Area of aortic}}$$

becomes more fully established.

And if it be also true, as it undoubtedly is, that equal volumes of blood must pass synchronously through the pulmonic and aortic openings, and that the two ventricles exert very unequal pressures during systole upon these equal volumes of blood, it must follow, if the velocities are unequal, that equal *times* of efflux can be only obtained by the areas of the aortic and pulmonic orifices being inversely as the velocities of the streams which traverse them. During the period of each systole the left ventricle has not only to sustain and neutralise the pressure of the aortic column, but also to send forth nearly five cubic inches of blood into that vessel. The latter is by far the smallest portion of its task, as shown in an able paper written by Dr. Andrew Buchanan, of the University of Glasgow, upon the "Effective Force of the Heart"; but the principle—the formula—for the truth of which I am contending (the result of the correlation of the forces of the two hearts), does not involve the objects for which the forces of the two ventricles are put forth. It is sufficient to know that the velocities are unequal—that they result from the operation of unequal forces which act in equal and the same times upon equal masses of blood traversing openings of confessedly unequal areas—to be convinced that these areas must be inversely as the velocities of the streams which pass through them. An American reviewer of my paper clearly puts it:—"Dr. Davies's observations relate only to the relation between the *size of the orifices* and to the average velocity of the blood through these orifices, and he deals with *vis viva* only on attempting, as it were, to confirm the latter."*

M. Onimus, in the *Journal de l'Anatomie*, 1865, has attempted to show that the auriculo-ventricular openings are completely closed in systole by muscular (sphincter) action, but the investigations of more recent anatomists completely negative the existence of such an arrangement of fibres; and with respect to one of these openings he himself says:—"Si pour l'orifice auriculo-ventriculaire on peut admettre des fibres circulaires formant des sphincters, pour l'orifice gauche cette expression n'est pas très juste, car cette dénomination suppose un muscle annulaire, et nous avons vu qu'une partie de cet orifice était complètement fibreux." In fact, the dissection of a heart which has been

boiled for some hours will readily show that the fibres at the auriculo-ventricular orifice have an almost vertical direction, and that their action would tend rather to keep the openings dilated than closed during the ventricular systole. I cannot believe also that any trust can be placed upon the very rough experiment described by M. Onimus of passing a finger through a wound made in the wall of the auricle of a living animal so that it may reach and be pushed into the ventricle through the auriculo-ventricular orifice. Fatal and sudden syncope would undoubtedly result and interfere with the experiment.

Finsbury-square, June, 1872.

INTESTINAL OBSTRUCTION OF FIVE DAYS' DURATION, CURED BY KNEADING, AFTER INJECTION PER RECTUM.

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F. G. H.—, aged forty, was attacked on the evening of Friday, Sept. 22nd, 1871, with great pain in the abdomen, quickly followed by severe vomiting. He had had a motion, natural in every respect, about midday; between that time and the commencement of his illness had lifted no weight, nor done anything to account for the symptoms under which he suffered. He had been a free liver, but had always enjoyed excellent health. He sent, on the morning of the 23rd, for Mr. Brookhouse, of Deptford, to whom I am indebted for the following account of his case:—

"On entering the room, I was struck by the anxious appearance of his face; he was crying out with pain, his hands placed over his abdomen, his thighs flexed on the pelvis. There was great pain in the epigastric region a little to the right of the median line, increased by pressure. The pulse was 80, normal in character; the tongue clean and moist; no hernia; he had had no shivering, and there was no evidence of peritonitis. The urine was very scanty and high-coloured. The matters vomited appeared to be gastric secretion with some bile. He was ordered to take a draught of chloral hydrate, twenty-five grains, in cinnamon-water, immediately, and a mixture containing carbonate of soda, tincture of opium, hydrocyanic acid, and spirit of chloroform, every three hours. Hot fomentations were applied over the abdomen, and an injection of castor-oil and turpentine in half-a-pint of gruel was administered. This brought away two or three hard nodules of fæces, and on the evening of the 23rd he was somewhat easier.

"Sept. 24th.—Morning: He passed a very bad night. The pain comes on in paroxysms, recurring every three or four minutes. A little to the right of the median line a small tumour is perceptible, which now and again disappears (? contraction of rectus muscle); the vomiting is constant of the same fluid as before; pulse 90. A second enema ordered.—Evening: The enema returned mixed with a small quantity of blood and much mucus. Ordered ice and one grain of opium powder every hour.

"25th.—Much worse; pain intense; sickness continual; abdomen somewhat tympanitic. In the afternoon he was seen by Dr. Hilton Fagge in consultation. The abdomen was then full, but not over-distended; the right loin, perhaps, offered more resistance than the left. To the right of the umbilicus and above it there was distinct hardness, which gave obscurely the impression that a transverse coil of bowel could be felt above, bending upon a vertical one below. This, however, may have been only the rectus muscle; for afterwards, when the legs were drawn up, it became less distinct. The tongue was rather dry; the skin warm and comfortable. The vomited matters were brown, with flocculi of a darker colour; but not stercoraceous. He was ordered a pill containing a quarter of a grain of extract of belladonna and a grain of opium every two hours; iced beef-tea and milk.

"26th.—Morning: Has passed a good night, and has had no pain or sickness since 8 o'clock last night.—Evening: Still better; but has passed nothing through the bowels. Urine still very scanty and high-coloured.

"27th.—Had no pain or sickness until 9 A.M., when both

* The American Journal of the Medical Sciences, Oct. 1870, p. 503.