Observations ON ARTERIES, NORMAL AND PATHOLOGICAL.

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In a paper¹ by one of us (J. A. MacWilliam) the remarkable persistence of vitality in the arteries of healthy animals excised after death has been described. It was shown that the arteries of the ox, horse, sheep, etc., retain the power of contraction for long periods (days) after the death of the animal. For a day or two, and sometimes longer, after death, they may be made to contract by the application of mechanical stimuli (cutting, etc.), exposure to air, cooling, etc., by chemical stimulation with chloroform vapour, etc. The contraction so excited may last until four days after death—in some cases much longer. The excitability to stimulation passes away much earlier than the persistent contraction excited by stimulation. Evidence was adduced that this persistent contraction is quite different in its nature from the rigor mortis of skeletal muscle. The physical properties (elasticity, etc.) of an artery in this state of contraction are very different from those of the same artery when relaxed, and some of the conclusions arrived at by Professor Roy² in his work on the elasticity of the blood vessels are vitiated by neglect of this consideration.

Striking differences are evident in the behaviour of the contracted and relaxed artery when tested in various ways. When a contracted artery is distended by internal pressure it is found that equal rises of internal pressure do not produce equal increments of cubic capacity; up to a certain point of maximum distensibility there are increasing augmentations of volume per unit rise of pressure, then diminishing increments. The level at which the maximum distensibility is seen varies according to the amount of muscular contraction present in the artery. A strongly-contracted vessel requires a pressure vastly above the normal blood pressure—for example, several hundred millimetres of mercury; whilst a feebly contracted vessel shows its maximum distensibility at quite low pressures—for example, one-half or one-third of the normal blood pressure, etc. Relaxed arteries, like veins, show their greatest distensibility when the pressure is raised from zero. Roy's view was that arteries are most distensible and elastic at about the normal blood pressure of the animal; he unwittingly used arteries in which a certain amount of contraction must have been present.

Arteries containing little muscle in their walls behave like feebly contracted or relaxed muscular arteries. Transverse strips of contracted and relaxed arteries, when stretched by successive addition of equal weights, show similar differences in their behaviour; the presence or absence of contraction may be deduced from the form of the extensibility curve obtained in each case, strips of contracted artery showing increasing elongations up to a certain point, then diminishing elongations, in contrast to a relaxed artery, which shows diminishing elongations from the beginning. A contracted artery relaxes when heated to 50°–55° C., a temperature which causes no obvious change in the calibre of an artery which is already relaxed. When the pressure in the interior of an artery is raised, the amount of lengthening which the tube shows varies very strikingly in contracted and relaxed vessels. An artery (carotid of ox) which becomes elongated 30 per cent. in the relaxed condition (induced by keeping at body temperature, or more slowly at room temperature) by a rise of pressure from 0 to 150 mm. Hg may show only 3 or 4 per cent. of elongation

when subjected to a similar rise of pressure in the strongly contracted state.* The bearing of this upon the production of tortuosity in arteries in the living subject is sufficiently obvious; the importance of a relaxed condition of the muscular coat in this respect in leading to elongation and tortuosity has been emphasized by Professor Clifford Allbutt.³

The discordant results obtained by various observers (Marey, Roy, and others) as regards the elasticity of arteries are in large measure explicable by the absence or presence (in varying degree) of *post-mortem* contraction in the arteries they used in their experiments.

Means of abolishing *post-mortem* contraction in arteries were found to be:

1. Freezing for a few hours.
2. Keeping at body temperature in a warm chamber (in 1 per cent. sodium fluoride solution or blood or oil).
3. Keeping in 1 per cent. sodium fluoride solution, etc., at room temperature for longer periods for a number of hours.
4. Exposure to ammonia vapour for a few minutes; or
5. Treatment with a solution of ammonium or potassium sulphocyanide.

The measurements of the arterial tube as regards lumen, thickness of wall, tunica media, etc., are, of course, very different in the contracted and relaxed states of the same artery.

In our present inquiry we have sought to determine the application of some of the foregoing results to the arteries of the human subject as obtained at *post-mortem* examinations, amputations, etc., with special reference to the behaviour of the vessels when cut across and measured, and when placed in the usual fixing reagents in preparation for microscopical examination. We have examined a large number of specimens, some obtained from amputated limbs, after death by accident (drowning, etc.), while the others covered a considerable variety of diseased conditions.

We find that in the majority of cases in which dissolution has been a gradual process of an exhausting nature, preceded by high temperature, etc., the arteries have shown no sign of contractility when they came to our hands from the *post-mortem* room twelve to twenty-four hours or later after death. They presented all the characters of dead relaxed arteries when tested in the various ways above referred to—the application of stimulating and relaxing agents, tracings of elasticity, etc.

On the other hand, we found that in many instances, especially in cases of relatively sudden death, the vitality of the arteries may not be so readily lost, and contractility may persist for very considerable periods. Thus the renal artery of a man who had died suddenly from cerebral haemorrhage showed decided contraction in response to stimulation (chemical) twelve hours *post mortem*. After stimulation it gave the elasticity curve characteristic of contracted as contrasted with relaxed artery—a transverse strip when weighted did not give the maximum elongation with the first weight, but increasing elongations (with equal increments of weight) up to a maximum followed by decreasing elongations. A portion of this artery put into the usual fixing and hardening fluids contracted markedly and showed a calibre and thickness of wall notably different from those of the same artery fixed in the relaxed state after vitality had been extinguished. In many other instances, both in the case of normal and pathological arteries, marked contraction has been seen to occur, especially in response to chemical stimulation (chloroform vapour, alcohol, formol, etc.) as long as thirty hours *post mortem*.

In arteries obtained from amputated limbs we have found prolonged "survival." Thus the brachial artery of a boy showed striking contraction when a portion was dissected out from the severed limb twenty-four hours after amputation, the lumen diminishing to less than one-half that of the relaxed vessel. A change of a similar nature was seen when another piece of the brachial was excised next day. On the third day no visible effect followed mechanical stimulation—cutting, etc.—though a faint response to chemical stimulation was still seen.

* No doubt changes other than muscular relaxation occur in the arterial wall on keeping till relaxation occurs, but there is evidence that the relaxation is the chief change.

Portions of arteries excised at various periods after amputation or death from various causes were placed in the usual fixing and hardening fluids.

1. Alcohol, beginning with 50 per cent., changed later to 75 per cent. and absolute alcohol; or absolute alcohol used at first.
2. Müller's fluid.
3. Formol, 5 per cent.
4. Saturated solution of corrosive sublimate in normal saline.

Even arteries which had undergone extensive pathological changes—thickening of intima, etc.—were often found to show marked differences in (a) and (b). Large arteries like the iliacs, carotids, etc., showed appreciable changes when contractility had been present, though in much less marked degree than in the smaller vessels with their relatively thicker muscular coats.

In various arteries examined (brachial, carotid, basilar, middle cerebral, renal, etc.) sections were found to show differences of 25 to 100 per cent. in the size of the lumen,

Fig. 1.—Brachial artery ($\times 120$) twenty-five hours after amputation.

Fig. 2.—Brachial artery ($\times 120$) fourth day after amputation.

Fig. 3.—Brachial artery ($\times 120$) twenty-five hours after amputation. Treated with ammonia vapour.

Part of each artery was immersed in the fixing fluid (a) without preliminary treatment, and part (b) after treatment with relaxing agents—freezing, ammonia vapour, keeping, etc. Transverse sections were afterwards made from each part, and compared as regards size of lumen, thickness of wall and of middle coat, degree of waviness of elastic lamina, etc.

Sections made from (a) and (b) showed little or no differences in the case of arteries possessing little or no muscle, or in arteries possessing a strong muscular coat, but in which contractility was almost or wholly absent. On the other hand, medium-sized and small arteries retaining marked contractility at the time they were put into the fixing fluid showed very important differences as regards the measurements of lumen, tunica media, etc., according as to whether they had been treated

and as much as 30 per cent., etc., in the thickness of the tunica media, as results of the presence or absence of contractility in the artery when it was placed in the fixing fluid.

The average degree of waviness or corrugation in the elastic laminae, and especially in the internal elastic lamina (fenestrated membrane of Henle), affords useful indications as to the state of the arterial tube. We say *average degree* because the contour of the lamina is not by any means always uniform round the tube, especially in pathological arteries. The natural waviness present

Fig. 4.—Transverse section of brachial artery ($\times 40$) twenty-five hours post mortem (no relaxation). Alcohol.

with relaxing agents or not. Arteries kept at room temperature till contractility had passed away gave results similar to those in which contractility was abolished by the methods already mentioned. Control sections were made of such relaxed arteries with and without treatment by freezing, etc.

Fig. 5.—Transverse section of brachial artery ($\times 40$) forty-nine hours post mortem. Alcohol.

even in the fully relaxed (empty) artery must be borne in mind. Messrs. Ballance and Edmunds⁴ have described the abolition of this waviness on distending the artery by a pressure approximately equal to the blood pressure. Our own experiments on the carotid indicate that when the vessel is distended to such an extent that its diameter in

the empty condition is increased by 20 per cent. the waviness is practically abolished. The varying degrees of corrugation in many published figures of arterial sections indicate that the vessels had been in different conditions as regards contraction (whether true muscular contraction or shrinkage) in these cases. Varying degrees of waviness are shown in Figs. 1, 2, and 3, drawn from

the presence or absence of contractility in the vessel at the time of fixing are illustrated by Figs. 4 to 17.

Of these, Figs. 4 to 7 represent sections of the brachial artery from the amputated limb of a boy. Fig. 4 refers to a section of a portion of the artery put into the fixing fluid

Fig. 6.—Transverse section of brachial artery ($\times 40$) fourth day *post mortem*. Alcohol.

sections of the same artery in different conditions. Fig. 1 is from a contracted artery; the internal elastic lamina is seen to be contorted, the curves being sharp and closely set; Fig. 2 is from the same artery kept so long that contractility has been nearly lost; and Fig. 3 is from the same vessel after contractility has been abolished by ammonia vapour; the waviness of the lamina is relatively slight—the ordinary waviness seen in an empty undistended relaxed artery. Occasionally in a relaxed artery pretty deep curves may be seen in the elastic lamina, but these are relatively wide apart when they occur,

Fig. 7.—Transverse section of brachial artery ($\times 40$) after ammonia. Alcohol.

(alcohol) twenty-five hours after amputation, when it was obviously alive and gave a striking response to mechanical and chemical stimulation. The smallness of the lumen and the thickness of the middle coat, etc., are to be noted.

Fig. 8.—Transverse section of basilar artery ($\times 40$). Case of pneumonia seven and a half hours *post mortem*. No relaxation. Formol, 10 per cent.

not in the close apposition seen in a contracted artery. (In Fig. 3 the least wavy part is shown).

Some of the results as regards differences in measurements, etc., in sections of the same artery depending on

Fig. 9.—Transverse section of basilar artery ($\times 40$). Case of pneumonia seven and a half hours *post mortem*. Frozen. Formol, 10 per cent.

(Fig. 1, showing strong corrugation of the internal elastic lamina, is from the same section.) When the artery was kept for a longer period—for example, forty-nine hours—before being put into the fixing fluid, contractility was

less marked; the appearances of the section are shown in Fig. 5. On the third and fourth days the artery showed no visible change when put into the fixing fluid; the section (Fig. 6) shows a large lumen, thinner middle coat, while the internal elastic lamina is much less corrugated (see Fig. 2). The same differences are seen in even greater degree in a portion of artery fixed at the same

Fig. 10.—Transverse section of basilar artery ($\times 40$). Case of pneumonia seven and a half hours *post mortem*. Ammonia. Formol, 10 per cent.

time as in Fig. 7, twenty-five hours after amputation, but after preliminary treatment with a relaxing agent—ammonia vapour in this instance—which abolished contractility speedily and completely (see also Fig. 3 for elastic lamina). Exposure to ammonia vapour was done simply by putting a few drops of ammonia into a small wide-mouthed bottle, and then suspending the piece of artery or placing it on a piece of cork, etc., to keep it from contact with the liquid ammonia while it was exposed to the vapour in the closed bottle. Treatment in this way for a very few minutes, varying according to the thickness of

Fig. 11.—Transverse section of middle cerebral artery ($\times 40$). Case of pneumonia thirty hours *post mortem*. Not frozen. Formol, 10 per cent.

the arterial wall, etc., suffices; too long exposure is injurious to the tissues.

Sections made after fixing with formol, sublimate, etc., instead of alcohol, gave results quite similar to those reproduced in the figures.

It must be noted that the phenomena of survival of arteries obtained from amputated limbs at similar periods after amputation may be very different in different cases. Thus, in the popliteal artery of a man thirty hours after amputation we found no evident signs of vitality and no

noteworthy differences in the sections of portions fixed at the same time and in the same way (a) without, and (b) with, preliminary treatment with relaxing agents.

Some results obtained from the basilar artery are illustrated by Figs. 8 to 10. These are from the artery of a man aged 60, who became maniacal, was removed to an asylum, and died very soon afterwards of pneumonia. There was no obvious response to mechanical stimulation, but the vessel was still susceptible of chemical stimulation. The result when the artery was put directly into the fixing fluid is shown in Fig. 8, the effects of previous treatment with relaxing agents in Figs. 9 and 10, freezing being employed in the case of Fig. 9 and ammonia vapour

Fig. 12.—Transverse section of middle cerebral artery ($\times 40$). Case of pneumonia fifty-four hours *post mortem*. Not frozen. Formol, 10 per cent.

in Fig. 10; the three portions were put into the fixing fluid at the same time and treated similarly afterwards. The differences in the sections obtained from the relaxed and the non-relaxed portions are sufficiently obvious.

Sections from the middle cerebral artery are shown in Figs. 11 to 13. The artery was obtained from the same patient as the basilar shown in Figs. 8 to 10, removed seven and a half hours *post mortem* and kept till thirty hours *post mortem*; part was put directly into the fixing fluid (see Fig. 11). Another part was frozen before fixing, with the results shown in Fig. 13. A third part was kept till fifty-four hours *post mortem*, then fixed without the application of any relaxing agent (see Fig. 12). The absence of contractility, whether from freezing or keeping, leads to very notable changes in the sections (Figs. 12 and 13) as compared with Fig. 11.

Figs. 14 to 17 refer to large arteries taken seven hours after death from a man, aged 34, who died of phthisis—an old-standing case with very extensive excavation of the right lung; death was due to pulmonary haemorrhage;

Fig. 13.—Transverse section of middle cerebral artery ($\times 40$). Case of pneumonia thirty hours *post mortem*. Frozen. Formol, 10 per cent.

emaciation was marked. Fig. 14 is from the internal iliac, put directly into sublimate, while Fig. 15 represents a section from the same artery which had first been treated with ammonia vapour. The differences, though distinct, are naturally less extensive than may be present in more muscular arteries. A similar remark applies to the sections of carotid from the same case shown in Figs. 16 and 17; the former was fixed in formol without preliminary treatment, while the latter was first treated with ammonia vapour.

From the foregoing observations it may be concluded that when death occurs by a relatively gradual exhaustive process the state of the arterial muscle at the time of death may be such that its contractility soon disappears, instead of being capable of persisting for considerable periods, as in many cases of more sudden death and of amputation, though even in the latter cases there are wide

serious fallacy, whether the artery is fixed *in situ* or after excision. Obviously this possibility is specially in question in cases in which the autopsy is made at an early period. In order to obtain constant and reliable results it is essential that contractility should be absent before proceeding to take measurements, and before placing the artery in fixing and hardening fluids with a view to the

Fig. 14.—Carotid ($\times 22$, reduced to two-thirds) seven hours *post mortem*. Formol, 10 per cent.

variations as regards the behaviour of the vessels after death—no doubt depending on varying conditions of the arterial muscle at the time. While presenting the same essential characters as in the healthy animals examined (ox, horse, sheep, etc.), *post-mortem* contraction in man has not been found, in our experience, to persist so long, at least in the adult. We have not seen any decided evidence of contractile reaction in the human adult so

Fig. 15.—Transverse section of carotid ($\times 22$, reduced to two-thirds) seven hours *post mortem*. Formol, 10 per cent., after ammonia.

preparation of sections. Disturbing changes of a similar nature are, of course, liable to occur in other organs and structures containing unstriated muscle, but probably in none of them are such effects of so much practical importance as in the case of the arteries.

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Fig. 16.—Transverse section of iliac artery ($\times 22$, reduced to one-half) seven hours *post mortem*. Corrosive sublimate.

long as two days after death, though such may be quite pronounced for more than thirty hours even in arteries that show pathological changes; and in children the persistence may apparently be much longer than in the adult in some instances. Our specimens have been mostly got from cases of death from various diseases; few from accident cases.

It is evident that the presence of contractility in an artery at the time it is fixed for microscopical examination, measurements, etc., must constitute a source of

Fig. 17.—Transverse section of iliac artery ($\times 22$, reduced to one-half) after ammonia. Corrosive sublimate.

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- ¹ *Proceedings of the Royal Society*, vol. lxx, pp. 109-153. ² *Journal of Physiology*, vol. lxx, p. 125. ³ *BRITISH MEDICAL JOURNAL*, January, 1906. ⁴ *Litigation in Continuity*, London, 1891, p. 52.

A NATIONAL Congress on Industrial Diseases will be held at Florence in May, 1909.