VI.—ON SOME OF THE PHYSIOLOGICAL AND THERAPEUTIC EFFECTS OF WATER AT DIFFERENT TEMPERATURES, WITH SPECIAL REFERENCE TO OBSTETRIC AND GYNAECOLOGICAL PRACTICE.

By R. Milne Murray, M.A., M.B., M.R.C.P.E., Physician for Diseases of Women, Western Dispensary, etc.

The great change which the introduction of the use of water at high temperatures has effected in the treatment of certain gynaecological and obstetrical complications, is one of extreme importance. If we are to judge of its efficiency by the accounts given of it by those who have made practical application of it, we are bound to admit that it is destined to revolutionize the treatment of inflammations and haemorrhages in other parts of the body than the pelvis.

For a long period the efficiency of cold applications in the checking of haemorrhage, under certain conditions, has been known and practised. For centuries, in the case of post-partum haemorrhage, for example, cold cloths to the abdomen, cold water and ice in the vagina, etc., have been regarded as routine practice, and their employment has been followed by undoubted relief of the symptoms in thousands of cases.

It is, on the other hand, within but very recent years that the use of water at, relatively speaking, high temperatures — at a temperature higher by 10° to 20° F. than that of the normal blood — has come to be recommended for the treatment of the same condition, and the experience of those who have employed it largely would go to show that its advantages far outweigh those of water at the lower temperatures.

The evidence of this greater efficiency of warm over cold water in controlling uterine hemorrhage is based almost entirely on clinical evidence. The effect is supposed to be a twofold one, namely, upon the uterine muscle itself, and upon the bloodvessels, causing, that is to say, rigid tonus of the uterus, and more or less persistent spasm of the muscular tissue of the other. The fact that a stream of hot water, directed on the bleeding surface during an operation for vesico-vaginal fistula, or for repair of the perineum, at once arrests haemorrhage, goes far to prove the second supposition; and the fact of the former is not difficult to demonstrate in a flabby and relaxed uterus after the third stage. Indeed, considering the intimate histological and physiological relations of the middle coats of the uterus and of bloodvessels, it is not difficult to suppose that a physical agent which affects the one must, in some degree at any rate, affect the other also.

Nevertheless, in spite of this more or less definite attempt at an explanation of its action, and the enthusiasm of many of those who have given it a trial, it is not a matter for surprise that in so
dire an emergency as post-partum haemorrhage, obstetricians should hesitate to abandon methods they have been taught and have practised, for one which seems indeed their very antithesis.

While cold has been universally admitted as the great agent for causing spasm of bloodvessels and of allaying haemorrhage, warmth, on the other hand, has been as widely credited with the opposite effect, that of the dilation of vessels and promotion of haemorrhage. The effect of a bath of tepid water on an incised and bleeding wound is familiar to all. That warmth, on the other hand, could, check bleeding seemed naturally but a paradox. Nor have the attempts which have been made to explain the astringent effect by the votaries of heat been by any means convincing.

Dr Emmett, whose name more than that of any other is associated with the advocacy of the use of hot water, in explaining the action of heat on the peripheral circulation, writes as follows:—“Heat, unless at a temperature which would destroy the parts, does not act as promptly in causing this contraction (of bloodvessels) as either electricity or cold. In fact, its immediate effect is to cause relaxation, and to increase the congestion of the parts; but if its application be prolonged, reaction ensues, and contraction takes place—in other words, the reaction from heat is contraction. The capillaries are excited to increased action, and as they contract from the stimulus of their nerves, the tonic effect extends to the coats of the larger vessels, their calibre in turn becomes lessened, and with this approach to healthy action their congestion is diminished. The popular belief is that heat relaxes and increases the congestion of parts, and such indeed is the case at first. But a hot poultice is never applied with the object of increasing the congestion, but as any ‘old wife’ would express it, to draw the ‘fire’ or inflammation out—in other words, it lessens the congestion by stimulating the bloodvessels to contract. . . . The immediate effect of cold, therefore, is contraction, and with reaction comes dilatation; but the reverse is true of heat, which causes at first dilatation, followed, however, by contraction.”

This extract is a striking instance of an attempt to square a preconceived idea with an observed fact. The author has held for years that warmth is a promoter of hemorrhage and a dilator of small bloodvessels, but he has recently found that warm water is efficient in contracting bloodvessels and controlling haemorrhage. He attempts to reconcile this apparent contradiction by affirming that the first effect is dilation, but the after-effect is contraction. I do not here stop to discuss the various physiological statements made in this extract, but would merely remark that it is but a sorry recommendation of hot water as a uterine haemostatic to an accoucheur struggling with a case of post-partum haemorrhage, to say, “Inject warm water into the uterus. It will certainly increase the
hæmorrhage at first, but if you go on long enough, the bleeding is bound to stop when the reaction sets in!"

Emmett is not singular in the failure of his attempts to explain the action of this agent, and it is well that others have paid less attention to the explanations given of its action than to the reality and efficiency of the action itself.

I have recently been engaged in investigating the action of stimuli of various sorts on the muscular tissue of the uterus, as well as non-striped muscle generally, and as the results bear in a very direct way upon the effect of heat and cold in controlling hæmorrhage and promoting muscular contraction, they have seemed to me of sufficient interest to warrant me laying them before the Society to-night.

I divide my paper into two parts. In the first I consider "The physiological effect of thermal stimuli when applied directly to muscular and vascular tissues;" and in the second I purpose making some deductions of therapeutic and practical interest from the results of these observations.

I. THE PHYSIOLOGICAL EFFECT OF THERMAL STIMULI ON NON-STRIPED MUSCULAR TISSUE.

The heat was applied by means of water, and for convenience I shall divide the temperatures experimented on into three divisions—

- a. Cold, from 32° F. to 60° F.
- b. Intermediate, from 60° F. to 100° F.
- c. Hot, from 100° F. to 120° F.

Mode of Experiment.—The experiments have been conducted on the uterus of rabbits both pregnant and non-pregnant. I have at previous meetings of the Society shown and described the mode of recording the observations and some of the tracings obtained, but for the sake of those Fellows here who may not have been present then, I may briefly recapitulate my description.

The animal being fully anaesthetised and secured, the abdomen is opened in the middle line from 1½ inches above the pubis down to that bone. The bladder, which is generally found to be distended, is emptied by pressure and pushed aside, and the vaginal tube or uterine cornu, as desired, is gently withdrawn from the abdomen. Supposing the uterine horn is to be made the subject of experiments, it is carefully raised from the incision, and adjusted at or near the vaginal end between the jaws of a gilt clamp, b, the latter being held firmly on an arm sliding on a rigid support. The clamp is compressed sufficiently to prevent the horn slipping out, but not so as to damage the tissues. When the vagina is to be observed it is raised in a similar manner, but care is taken to arrange the vessels which run along the anterior and posterior aspects of it, so that they lie in the space between the jaws, and are not compressed by them. To the further end of the horn or
vagina, as the case may be, a fine steel hook, $a$, is passed into the tissue. From this hook a silk thread passes under a pulley, $c$, on the horizontal rod, $d$, and then to a short lever, $e$, moving in a vertical plane. From this lever a second thread, $f$, passes over another pulley to the lever, $h$, which writes on the drum. It will be seen from this arrangement that any shortening of the segment held between the clamp and the hook will draw upon the latter and so elevate the writing lever, and so long as the parts remain as adjusted, the various movements of the lever will represent a proportional shortening of the segment under observation.

With an arrangement such as this the finest movements of the
uterine muscle in a longitudinal direction are recorded with accuracy. Slight contractions, which will certainly escape the eye of even a trained observer, are demonstrated by the lever, and the perfectly comparative value of the different tracings in a given experiment is not its least recommendation.

The tracing may be taken on smoked or continuous paper. As the drum must move very slowly, the former is the most convenient method, though for any long observation the latter may have its advantages.

When the vagina or uterine horn of a rabbit is arranged as described, evidence is invariably afforded of the existence of regular contractions of the muscular wall, and resulting in rhythmic shortening of the tube. It will be found that the lever describes a series of up and down movements, representing regular contractions and relaxations of the portion of muscular tissue under observation. The rate at which this movement occurs is somewhat variable in different individuals. In young animals it is more rapid than in full-grown individuals.

I show first a tracing, Plate I., Fig. 1, which shows the movement obtained from the vagina of a half-grown animal, in which the rate is at about one contraction in 35 seconds.

In Fig. 2, obtained from the vagina of a full-grown animal, the contractions occur at the rate of one in 115 seconds, as seen in the upper line.

In Fig. 3 A, also from an adult, the movement is at the rate of one in 180 seconds. On an average the rate in the adult may be stated as one in 120 seconds.

In the uterine horn the movements are less extensive than in the vagina, but occur at the same rate, and are always perfectly obvious. They present an important difference in certain respects which I shall have occasion to refer to later on.

The movement as observed by the eye is a distinct peristaltic one. In the vagina, where it is best seen, the contraction begins at the clamp, the tube gradually shortens, while a circular bulging and constriction travels slowly along, the tissue of the segment becoming pale and bloodless.

The movement, if uninterfered with, will go on for hours, its rhythm and extent undergoing little or no change. I have observed it repeatedly for six hours, in one case for nine. It, moreover, continues for a variable period after death, from 30 to 65 minutes. It can be abolished by deep chloroform anaesthesia, but not readily by ether.

The elements going to make up the curves obtained are a matter of some interest, not only on account of the remarkable persistence of their features in different tracings, but also in the case of those obtained from the vagina, on account of the striking resemblance which their component parts bear, at first sight at least, to those obtained from simple contractions of striped muscle.
On examining any of the tracings obtained from the vagina, Figs. 1, 2, or 3, Plate I., it will be seen that each curve consists of three well-defined parts—

1. A period of contraction.
2. " of quick relaxation.
3. " of slow relaxation.

These are particularly distinct in Fig. 3.

The invariable occurrence of these three phases in any curve of contraction shown is worthy of notice. But we must beware of pressing the analogy between the contractions of such an organ as the vagina and that of a portion of striped muscle such as the gastrocnemius of the frog. In this case we are dealing with a tube whose walls are made up of a more or less complex arrangement of non-striped muscular bundles. In the other, we are dealing with a simple muscular element. However interesting may be the fact that the two curves are similar, we are not at liberty to conclude that the mode of action of striped and non-striped muscle is identical. I direct attention to this feature of these records at present in order to enable me the better to point out the more clearly how these movements become modified by the agencies I am about to discuss. A knowledge of the existence and features of these contractions will enable me further to explain what would otherwise seem discrepancies in the result of some of my observations. The question, however, naturally arises here—"Are these rhythmic contractions constantly present in the uninjured vagina and uterus of rabbits, or are they called forth by the operation necessary for their observation, or by the cold air and other influences to which the organ is exposed?"

I have not time at present to enter into a consideration of this question with the detail it demands (nor is it essential for my present purpose), but I beg to submit the following points in support of the view which I hold, that these rhythmic contractions are not the result of adventitious stimuli, but that the whole uterine apparatus of rabbits, and presumably of other animals as well, is the seat of regular rhythmic contractions, independent altogether of pregnancy.

1. The contractions present the same characters in all the animals observed, and in the same individual continue for hours, without any noticeable variation of rate or extent.
2. Variations in temperature of the surrounding atmosphere, and variations in the amount of stretching or compression within wide limits, have no effect on the rate or extent.
3. The contractions continue for many hours where the uterus is returned to the abdomen immediately after the attachment of the hook, and their character is quite similar to those obtained from an exposed uterus.
4. Contractions induced by direct stimuli, thermal and other, differ entirely in many of their features from the natural ones.
5. In this connexion an experiment, which I was enabled to
make, by the kindness of Dr Croom, in the Maternity Hospital last autumn, has a special interest.

A Barnes' bag containing water, but not distended by it, was introduced into the vagina of a pregnant primipara, and the tube attached to a water manometer. Fig. 4, Plate I., shows the result, and gives evidence of a distinct and rhythmic rise and fall of pressure in the vagina.

From these and other considerations I am of opinion that these contractions, representing a regular peristalsis of the whole muscular wall of the uterus and vagina, exist independently of all external stimuli. They are, apparently, examples of automatic action, and are most probably concerned with the nutrition of the muscular apparatus.1

I have now to consider the results obtained by the application of water at different temperatures to such a portion of uterus or vagina as I have described.

In order to eliminate the effect of the water itself apart from its thermal condition, I made some preliminary observations with pure water at temperatures from 90° to 100° F. It is well known that striped muscle is thrown into a state of rigidity by being immersed in pure water, the condition being known as "water-rigor." Pure water, however, at temperatures varying between 100° F. and 90° F., has no such effect on non-striped muscle. Water at such temperatures, and, indeed, as low as 65° F., produces in some cases no appreciable effect; in others, it seems to diminish the extent of the rhythmic contraction, while having little if any effect on the rate. Nothing of the nature of a prolongation of the contraction was in any way noticeable.

In order to obtain reliable comparative results as to the effects of various temperatures, the water was applied in a definite quantity, as far as possible immediately after the disappearance of one of the rhythmic contractions. In this way the error, arising from the effect being complicated by the occurrence of the natural rhythm, was excluded to a great extent. The fact that the muscle was at the moment of stimulation presumably in a state of partial exhaustion—the result of the preceding contraction—does not vitiate the comparative value of the results. On the contrary, it enhances their interest from a practical point of view, in showing how far the efficacy of the artificial stimuli may be independent of the potential state of the organ for the moment.

The water was applied to the portion of muscle under experiment by means of a glass pipette of 5 c.c. capacity. The pipette was, first of all, immersed in water of the temperature to be employed, then filled, and allowed to discharge on the portion of muscle between the hook and clamp (see woodcut). In the earlier experi-

1 These movements have been observed and described by Jastreboff, Dembo, v. Basch and Hofmann, and others, but have not, so far as I am aware, been previously recorded in this fashion.

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ments the moment of contact of the water and tissue was marked on the drum by an assistant; in the later ones the whole period of application was recorded by means of an electric signal, whose indications are obvious in the tracings.

In describing the effects I shall keep those upon the muscular tissue separate from those on the vascular apparatus, treating of the former first.

A. Effects of direct application of Water at 60° F, and under to Non-striped Muscle.

The results of such an application will be most satisfactorily considered under the following divisions:

1. The duration of the latent period, i.e., the length of time elapsing between the first contact of water and the first indication of effect.
2. The modification which such effect produces on the elements of a rhythmic contraction.
   a. Its period of contraction.
   b. Its period of quick relaxation.
   c. Its period of slow relaxation.

I shall describe, first, a typical experiment with water taken directly from the tap, the temperature being 42°. The upper line A, Fig. 1, Plate II., shows the result of such an experiment. The X shows the moment of application of the water. It is followed—(1.) By a latent period extending to 30 seconds; (2.) This is succeeded by a period of contraction occupying 25 seconds.

On comparing this curve with any of those of the normal contractions already shown, it will be seen that this differs entirely on account of the absence of the quick upstroke—1—in other words, the contraction takes place slowly; (3.) So soon as the contraction reaches its maximum, it will be seen that the curve slowly begins to return to the abscissa. There is no prolongation of the maximal tonus. In this it agrees with the normal curves. But it differs in this important respect, in so far that there is no period of quick relaxation, which I pointed out was a characteristic feature of the normal curves. On the contrary, the curve slowly returns to the abscissa, taking 3 minutes 15 seconds to reach it.

Fig. 2, Plate II., shows the characteristic features distinctly. The first part of the tracing shows the normal rhythm extremely well, the sharp upstroke of the contraction, the quick relaxation period, and the slow after action. The drum was stopped after two contractions for 2 minutes, and the water at 5° C. = 41° F. applied after starting it again. On this occasion it happened to touch the tissue at

1 The tracings Figs. 1 and 2, Plate I., and Fig 1, Plate II., were obtained by an arrangement in which the thread was attached below the lever, the latter being held up by means of a fine elastic thread. The contraction of the muscle thus produces a downstroke, but its meaning is obvious. The arrangement figured in the cut was found more satisfactory, and was adopted for all the other experiments.
the moment when another natural movement was commencing. Consequently the latent period is abolished, and it will be seen that the first part of the curve corresponds in rate and character to that of the two preceding waves. At the horizontal line the slow developing contraction, due to the cold water, manifests itself. It reaches a maximum in 2 minutes 12 seconds, and the abscissa is reached in 7 minutes 35 seconds afterwards.1

I need not stay to describe more of these in detail. The features, then, of a single application of cold water under 50° F. to the exposed uterine horn or vagina are as follows:—

1. A latent period of from 40 to 90 seconds.
2. A period of contraction, occupying 1 to 5 minutes in reaching a maximum.
3. A period of relaxation ranging from 3 (nearly) to 15 minutes, generally, indeed, occupying three times the time of the contraction.

Such a series of phenomena has been practically constant in my experience, gathered from a large number of experiments. The only instances in which the latent period has been markedly diminished have been those in which the application of the stimulus coincided with the initiation of a natural rhythmic contraction. Water, which has been cooled by means of ice to 33° or 34° F., produced an almost identical effect. The latent period is reduced to 40 seconds in some, but not in all, cases, and in one or two instances the contraction has been slightly more rapid, but in these cases the period of relaxation has been proportionately shortened.

On the other hand, water between 50° and 60° F. differs in its action only in degree. 1st, There is a lengthening of the latent period; 2nd, The same slow contraction, which is of less extent and shorter duration than with the lower temperatures; 3rd, A relaxation period, which is of the same character as that described, but is proportionately shortened. This much for single applications of water at low temperatures.

1 It is necessary to explain that, owing to the duration of the contractions produced by these stimuli, the drum frequently completed its revolution before the lever had returned to the abscissa. The duration of the contraction after the revolution of the drum was noted by the following device. At the moment when the drum had completed its revolution, a platinum tongue carried by the drum completed an electric circuit by touching the surface of a mercury cup underneath. The current actuated an electro-magnet, which started a chronoscope capable of recording one-fifth second. At the moment when the contraction disappeared and the lever returned to the abscissa the chronoscope was stopped, and the duration recorded added on to the tracing.

(To be continued.)