

But sanatorium treatment and, even more important, hospital treatment of consumptives on the lines indicated in previous paragraphs must form an essential part of a satisfactory programme for the treatment and control of tuberculosis.

The Local Government Board's grants to local authorities for the institutional treatment of tuberculosis have not yet reached a quarter of a million of money in any one year. If to this be added the sum spent on the institutional treatment of insured consumptives, after deducting the contributions of insured persons and employers, the total cost borne by Government funds is certainly less than half a million sterling per annum. This is apart from local expenditure.

Housing and institutional treatment for tuberculosis cannot properly be regarded as alternatives. They are necessary complements to each other, and there must be increased expenditure in both directions. Housing is a problem in two divisions: For the healthy and for the sick. Special housing in institutions is needed for the sick when the care which their condition requires is not available in the home of the patient. This is true, whether the patient will be cured by the institutional treatment or not. But it is the duty of administrators so to arrange the conditions of admissions to, and continued treatment in, institutions that the provision will be used in the most economical and efficient manner possible, consistent with the welfare of the patients concerned.

STERILISATION BY DAKIN'S SOLUTION AND THE OCCURRENCE OF SECONDARY HÆMORRHAGE.

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SINCE the treatment of septic wounds is of prime importance and great improvements are being effected in it, no excuse is necessary for reinvestigation by a novel method of the relative potency of certain antiseptics which are fashionable at the present time. An impartial judgment from time to time of the value of the methods in use and of others proposed proves of direct benefit to the wounded under treatment. Such inquiries are indeed required to safeguard the patient against methods, which although new or modifications of older procedures, are not based on adequate trials, and against methods which the wounded have seen described in the lay press and feel aggrieved at not receiving.

Object and Nature of Present Inquiry.

The ideal antiseptic has yet to be found, all those in use possessing certain disadvantages. The present inquiry had its origin in the question of whether or not secondary hæmorrhage is more frequent under some forms of treatment at present in vogue than in others, suspicion having been aroused that the walls of healthy vessels lying exposed in wounds might be corroded by the antiseptic solution employed. The histological investigation of vessels from which secondary hæmorrhage had occurred has not lent support to this suspicion, as, without exception, they were found to have suffered previous damage. In a few cases the damage was purely physical, and in one instance this physical injury was associated with an aseptic thrombosis. In most cases septic thrombosis was present. In yet others the bleeding point was surrounded by granulations, showing that corrosion was not the cause of the hæmorrhage. In another paper I have discussed the frequency of thrombosis in association with infected wounds.¹

Resort was had to experiment with chloramine, Dakin's solution, Lorrain Smith's solution (eusol), and flavine. For purposes of comparison parallel experiments were made with iodine and mercury perchloride.

The method adopted consisted in the immersion of living tadpoles in various dilutions of the substances to be tested, one advantage thus gained being the elimination of the question of soaking the skin with water, such as occurs when watery fluids are applied to wounds. The experiments were performed at a temperature of 24°-26° C. The following observations were made.

1. By snipping off the tail, some distance from the anus, and dropping it into broth, it was first ascertained that the skin of the tails of the tadpoles yielded a heavy growth of Gram-positive and negative organisms—bacilli, streptococci, and also coliform bacilli—and were therefore suitable for this investigation.
2. The lethal concentrations of the several solutions for the tadpole were then determined, and the condition of the tails as regards sterility ascertained immediately after death, the nature of the lethal action being left out of consideration as immaterial.
3. When a minimum dilution, sterilising the skin of the tail at death had been found, a new series of experiments was made to ascertain if sterilisation could be effected in non-lethal solutions.
4. Thereafter the minimum time required to sterilise the tails was ascertained, and then was compared with the time required to cause the death of the animal.
5. Finally, the corroding or digestive action of the several solutions on the abdominal wall was noted.

After the preceding necessary preliminary experiments had been carried out the whole series of observations could be combined simultaneously in a long series of beakers, each containing one or more tadpoles immersed in increasing dilutions of the substance or substances. The accompanying tables give the results of such series of experiments.

TABLE I.—Dakin's Solution (Diluted to give the Concentration of Hypochlorite shown in Column 1).

Dilution of hypochlorite.	Average time required to cause death.	Condition of skin of tail at death.	Minimum time required to sterilise skin of tail.	Time required for abdominal wall to rupture.
1 : 1,000	3 min.	Sterile.	3 min.	35 min.
1 : 2,000	6 "	"	3 "	3 hrs.
1 : 4,000	12 "	"	5 "	4 "
1 : 10,000	18 "	"	5 "	44 "
1 : 25,000	30 "	"	10 "	Action absent.
1 : 50,000	35 "	"	16 "	"
1 : 100,000	60 "	"	30 "	"
1 : 500,000	Alive after 24 hrs.	Sterile after 4 hrs.	—	"
1 : 1,000,000	"	Not sterile after 24 hrs.	—	"

TABLE II.—Eusol (Diluted).

Dilution of hypochlorite.	Average time required to cause death.	Condition of skin of tail at death.	Maximum time required to sterilise skin of tail.	Time required for abdominal wall to rupture.
1 : 2,000	5 min.	Sterile.	2 min.	5 hours.
1 : 4,000	6 "	"	3 "	Action absent.
1 : 10,000	8 "	"	4 "	"
1 : 25,000	16 "	"	5 "	"
1 : 50,000	35 "	"	12 "	"
1 : 100,000	60 "	"	30 "	"
1 : 500,000	Alive after 24 hrs.	"	—	"
1 : 1,000,000	"	Not sterile after 24 hrs.	—	"

TABLE III.—Chloramine.

Dilution of antiseptic.	Time required to cause death.	Condition of skin of tail at time of death.	Minimum time required to sterilise skin of tail.	Time required for abdominal wall to rupture.
1 : 50	18 min.	Sterile.	3 min.	No appreciable solvent action.
1 : 100	25 "	"	6 "	"
1 : 200	35 "	"	10 "	"
1 : 400	45 "	"	15 "	"
1 : 1,000	1½ hrs.	"	25 "	"
1 : 2,000	2 "	"	30 "	"
1 : 4,000	2¾ "	"	1½ hrs.	"
1 : 10,000	5¼ "	"	1¾ "	"
1 : 100,000	Alive after 24 hrs.	Not sterile.	Not sterilised.	"
1 : 500,000	"	"	"	"
1 : 1,000,000	"	"	"	"

¹ British Journal of Surgery, April, 1917.

TABLE IV.—Flavine.

Dilution of antiseptic.	Average time required to cause death.	Condition of skin of tail at time of death.	Minimum time required to sterilise skin of tail.	Time required for abdominal wall to rupture.
1 : 1,000	1 hr.	Sterile.	$\frac{1}{2}$ hr.	No solvent action.
1 : 2,000	2 hrs.	Not sterile.	Not sterilised.	"
1 : 4,000	3 "	"	"	"
1 : 8,000	8 "	"	"	"
1 : 16,000	16 "	"	"	"
1 : 32,000	Alive after 24 hrs.	Not sterile after 24 hrs.	"	"
1 : 50,000	"	"	"	"

TABLE V.—Iodine.

Dilution of antiseptic.	Average time required to cause death.	Condition of skin of tail at death.	Minimum time required to sterilise skin of tail.	Time required for abdominal wall to rupture.
1 : 10,000	5 min.	Sterile.	3 min.	No solvent action.
1 : 50,000	20 "	"	20 "	"
1 : 100,000	30 "	Not sterile at death.	—	"
1 : 250,000	1 hr. 50 min.	"	—	"
1 : 500,000	2½ hrs.	"	—	"
1 : 1,000,000	Alive after 24 hrs.	"	—	"

TABLE VI.—Mercuric Chloride.

Dilution of antiseptic.	Average time required to cause death.	Condition of skin of tail at time of death.	Maximum time required to sterilise skin of tail.	Time required for abdominal wall to rupture.
1 : 2,500	11 min.	Sterile.	4 min.	No solvent action.
1 : 5,000	13 "	"	4 "	"
1 : 10,000	30 "	"	15 "	"
1 : 100,000	1½ hrs.	"	45 "	"
1 : 500,000	2½ "	"	2 hr.	"
1 : 1,000,000	4 "	"	More than 2 hrs.	"
1 : 5,000,000	5 "	Not sterile.	—	"

Results of Experiments.

A comparison of the tables shows that Dakin's and Lorrain Smith's solutions (Tables I. and II.) are practically parallel both in their lethal effects and in their power to sterilise living tissue, the latter action taking place in, roughly, half the time required to produce death, but that the solutions differ in their power to digest dead tissue. Although in the table eusol is shown as digesting the abdominal wall in five hours, it should be noted that the effect was in no way comparable to that obtained with the highest dilution of Dakin's solution having this action. In higher concentrations of Dakin's solution the tadpole, after dying, was speedily reduced to a little heap of sand representing the intestinal contents, but with eusol this result was not obtained.

Chloramine (Table III.), by comparison with Dakin's solution and eusol, is shown to be relatively less toxic to the animal and the minimum time required to sterilise the tail is a much smaller fraction of the time required to kill the animal, being roughly $\frac{1}{4}$ contrasted with a $\frac{1}{2}$ for the former substances. These three preparations have, therefore, the common property that lethal action and bactericidal effects exercised upon the surface can be separated.

Flavine (Table IV.), or to be quite correct the two samples examined, has not the same power to sterilise the skin of the tadpole's tail. The figures given in the table were the best obtained in four series, sterilisation having been obtained only once at death by a dilution of 1 in 2000.

Iodine (Table V.) and mercury perchloride have only been tested for the purposes of control, because, so far as I am aware, the method employed has not before been applied to a comparison of antiseptic power. For iodine it may be noted that it is efficient—a point of interest—because it is so extensively employed as an application to the skin of the wounded, as well as in other circumstances. Mercury

perchloride calls for no comment beyond a reference to the figures (Table VI.) as ascertained. The only point of interest in the present connexion is that with these substances lethal action and bactericidal power coincide in the higher dilutions. This is also the case for the strongest concentration of flavine, bactericidal power and lethal action not being separable.

Limitation of Corroding Action.

As the question of the corroding action of Dakin's solution on the walls of healthy vessels has been raised in connexion with secondary hæmorrhage, and is one of importance, a series of experiments have been made on this subject. It is well to show how this deleterious action can probably be excluded by the present observations.

The anterior abdominal wall of the tadpole is a delicate membrane formed mainly of two layers of cubical cells. Normally the intestines do not show through the anterior abdominal wall, whether in the living or newly dead tadpole; but in the event of a corroding or digestive action, the wall thins and they soon begin to be visible. Finally, rupture of the abdominal wall is indicated with great exactness by the intestines being set free and shooting out, somewhat like a watch-spring released. A tadpole having been killed by immersion in water in which a trace of chloroform had been shaken up, was put into a beaker of hypochlorite solution simultaneously with a live tadpole of the same size, and the time required for digestion of the abdominal wall noted in the two cases. Results such as the following were obtained:—

Dakin's Solution.

Dilution of hypochlorite.	Time for abdominal wall to rupture.	
	Tadpole immersed when dead.	Tadpole immersed when living.
1 : 1000	30 minutes.	40 minutes.
1 : 2000	2½ hours.	3 hours.
1 : 4000	3 hours 40 minutes.	3 hours 55 minutes.

In such an experiment the action of the solution on the abdominal wall while the circulation remains intact for some time is contrasted with its action on the same delicate and still living membrane after the services of the circulation have been impaired or entirely lost. The differences between the time required for the abdominal wall to rupture in the living and the dead animal respectively are larger than the interval required to produce death, as shown in column 2 of Table I.²; and hence the vitality retained by the skin immediately after death of the animal offers resistance to the digesting action of the fluid. Moreover, if living tadpoles be compared with those that have been kept in water for an hour after death, the difference is greatly increased, showing that the more vitality is impaired, the more readily the tissue is attacked, and probably that dead tissue is immediately attacked. Therefore the activity of the circulation and the retention of local vitality place limitations on the corroding action of Dakin's solution, while on the other hand the absence of a circulation and reduced vitality promote this action.

It would appear from the above table as if the local action of Dakin's solution was held in check by an efficient circulation either by providing protein-containing fluid or by carrying off and rendering harmless the hypochlorites as they approach living tissues without entering into combination with them—i.e., killing them. It seems reasonable to infer from experiments with such a delicate membrane that equilibrium between the two processes is well established within an extremely narrow zone of tissue—in this case two layers of cubical epithelial cells—and is an expression of the limited extent to which Dakin's solution, owing to its great lability or chemical instability, can penetrate or injure living tissue in the presence of an efficient circulation.

² Death occurred, for 1 : 1000 in 3 and for 1 : 2000 in 6 minutes; for 1 : 4000 in 12 minutes. The differences are therefore 7 and 23 minutes respectively for the first two dilutions. The approximation of the times for the living and the dead tadpoles shown in the above table is characteristic of all reactions taking place in the extremes of dilutions at which they occur at all, and may be left out of the argument, except in so far as the table shows on the whole, that, if action on living tissue does not commence during complete vitality, still an impairment of vitality by the solution itself cannot be excluded, and that the solvent action is probably being attempted all the time, and becomes efficacious immediately whenever the impairment, short of death, becomes sufficient. Further observations are in progress on the action of the hypochlorites on the web of the frog's foot both when the circulation is active and arrested.

This liability has been urged as a disadvantage, and certainly the necessity for repeatedly renewing the supply of the solution is a practical inconvenience; but the very liability of the hypochlorites is probably the essence of their efficacy in wound treatment, as contrasted with antiseptics of known stability; and it still remains to be proved that the application of hypochlorites through other than watery media is equally efficacious, as in their application by means of the oily media now undergoing trial, and which it is hoped may act as reservoirs parting slowly with the active ingredient and therefore not requiring frequent renewal.

The other substances as tested are devoid of this solvent action on dead tissue, which, unless of the highly delicate and easily balanced nature characteristic of Dakin's solution, may readily be dangerous as in the case of the ferments. The abdominal wall of a living mouse is rapidly digested by 1 c.c. of a 1 per cent. suspension of Fairchild trypsin, so that the intestines lie free from the cavity in a quarter of an hour, whereas 30 times this quantity of trypsin is borne without any evident effect when injected intravenously.

Secondary Hæmorrhage.

I have heard different opinions expressed as to the manner of action of Dakin's solution. The foregoing observations seem to make it clear that in a septic wound it acts both as an antiseptic and as a cleansing agent or remover of dead tissue liable to serve as a nidus for micro-organisms. The latter are caught, as it were, between two fires, the antiseptic action of the hypochlorites, on the one hand, and the natural defences of the living tissues with which they are brought in direct contact on the other. It may, of course, be a disadvantage to remove, say, all healthy fibrinous exudate from the surface of the wound, but this is more than counter-balanced by the removal of all dead tissue. The removal of dead tissue is extremely well exhibited in a case brought to my notice by Captain F. L. A. Greaves, R.A.M.C. The anastomotic magna had been ligatured in an open wound and the visible free end, under the action of Dakin's solution, began to show signs of disappearing, so that the occurrence of secondary hæmorrhage was feared. Nothing of the kind happened, however, the erosion stopping just before the point of ligature was reached.

Were the erosion of sound vessels the usual cause of secondary hæmorrhage this accident would occur in practically all cases. The evidence adduced above to the effect that erosion of the delicate epithelial membrane covering the abdomen of the tadpole is resisted by its local vitality may legitimately be taken as evidence that the same holds for man in view of the experience gained in the treatment of wounds. Part of the frequency of secondary hæmorrhage may be due, not to the action of the solution, but only to its improper application, say by pressure of the point of the Carrel's instillation-tube badly applied, and thus leading to injury. Where, however, secondary hæmorrhages are common or gross, or obvious septic thrombosis can be excluded, the accident should be regarded rather as an indication that the surgeon to-day can preserve wounded limbs damaged to such a degree that earlier in the war either the wounded man died or the limb was amputated. Even the most careful cleansing now habitually carried out may fail to detect small injured or infected vessels with or without thrombosis, from which the bleeding apparently almost always arises. The position in regard to secondary hæmorrhage appears to me to be very similar to that attending the occurrence of local tetanus or the more familiar post-diphtheritic paralysis. Both the latter accidents are met with as a result of successful attempts in saving life.

During the war much has had to be learned as to dressing or treating septic wounds as contrasted with those of intentional surgery, and although the goal has not yet been reached great progress has been made so far as one who is not a surgeon, although constantly observing wounds at a general hospital and a surgical observation hut, can judge.

Victor Hugo, writing of events supposed to have taken place in 1832, tells us: "The dressings were complicated and difficult and it was not without difficulty that chloruretted lotions reached the end of the gangrene" ("Les Misérables"); and perhaps had the beneficial eras of antiseptic and aseptic surgery not for the time banished such wounds as Victor Hugo alludes to, we should have been better prepared for the proper application of the hypochlorites, or have already obtained improvements on them.

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THE RETRACTION OF BLOOD-CLOTS,

WITH TWO METHODS FOR SECURING A LARGE YIELD OF SERUM.

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I. THE EXTERNAL FACTORS.

IN spite of the large amount of work that has been directed to the study of the coagulation of the blood, comparatively little attention has been attracted to what is in reality a part of the process—namely, the retraction of the clot by which the serum is squeezed out. The question is of much theoretical interest, and now that so much use is made of serum in diagnosis and treatment, of some practical importance. In this and a subsequent article I propose to discuss the theory of the process, and to describe two methods by which a very full crop of serum may easily be obtained.

The Process of Retraction of the Clot.

The main phenomena are well known.

Blood when drawn from the living body, and collected in a non-living vessel, clots after a longer or shorter time. At first the clot is a uniform, soft, mass. After a period which varies from a few minutes to several hours, it usually begins to contract, and in doing so squeezes out from itself a larger or smaller amount of serum, mixed, in most cases, with red corpuscles and leucocytes. This serum usually makes its appearance in two situations—between the clot and the sides of the vessel, and on the surface of the clot—where at first a few small drops of serum appear, which, by their coalescence, form ultimately one or more large drops, or a complete layer of fluid. The clot is heavier than the serum, and tends to sink, so that when the process is completed it forms a dark purplish mass, having approximately the shape of the containing vessel, lying at the bottom of a greater or smaller amount of serum.

When clotting takes place a fine network of filaments of fibrin is formed, enclosing within its meshes serum, red corpuscles, and leucocytes. This is the first stage of the process, or coagulation. In the second stage, or retraction, each filament tends to contract, and, when it can do so successfully, the serum and some of the red corpuscles are squeezed out, and a firm mass of fibrin containing a comparatively small number of red corpuscles is left. The leucocytes, I may add, almost certainly make their way through the clot by their own active movements: the serum and red corpuscles are, of course, squeezed out mechanically.

A little consideration will show that the effects of this contraction of the fibrin filaments will differ fundamentally in the centre and at the periphery of the clot. If we consider a point in the centre of the clot (say a red corpuscle surrounded by a network of fibrin) we shall see that it is exposed to equal and opposite tensions in all directions, and as a result there is a general raising of the pressure in the mass, but no tendency for the movement of the serum or of the corpuscles in any one direction rather than in another; just as a sponge lying at the bottom of the ocean and permeated with water under high pressure will be neither compressed nor expanded. Retraction, therefore, must commence at the periphery—either at the sides of the vessel or at the surface of the clot. Here the conditions are quite different. Consider the case of a point lying in contact with the wall of the vessel. It also will be pulled on by fibrin filaments, but not in all directions. Those filaments which lie parallel to the surface in their contraction will have exactly the same effect as would be exerted by a stretched membrane surrounding the clot, tending to compress it and make it smaller. Those which are not parallel to the surface are either vertical thereto, in which case they tend to pull the clot away from the containing vessel, or at an angle, in which case they can be divided into their horizontal and vertical components, one tending to make the clot contract, the other pulling it away from the glass. At first these tensions are balanced by the adhesion of the

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It would have been impossible for me to perform the numerous simple but tedious experiments, of which examples are given, without the able assistance of Private T. C. Reynolds, R.A.M.C. In conclusion, I have to thank Colonel H. E. Cree, A.M.S., for granting me facilities for carrying out this investigation.