PRESENT-DAY METHODS OF STERILIZING DRESSINGS

BY

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The modern ritual of asepsis enables surgical procedures to be carried out with an almost monotonous freedom from complications caused by infection. Nevertheless from time to time disturbing features arise that have not up to now been satisfactorily explained. A surgeon finds wounds that should heal by first intention breaking down. Cases of tetanus following operation are occasionally reported. The obstetrician has sporadic cases of infection, and hospitals and nursing homes are afflicted—fortunately rarely—by epidemic sepsis. For many years my own work has been partly concerned with highly infected labour cases. It was not difficult to imagine that unless the aseptic technique was efficient spread of infection involving “clean” labour and gynaecological cases was not improbable. This led me five years ago to undertake the investigations outlined in this paper.

The sterilization of boilable articles for fifteen minutes is generally accepted as efficient. The sterilization of dressings, although accepted, appeared to be something of a mystery. My own knowledge was scanty. I knew that dressings such as abdominal sheets, towels, swabs, wool, overalls, gauze, caps, masks, etc., were packed into drums or bags and placed in a sterilizer into which steam was admitted until a certain pressure was reached; twenty minutes later the dressings were considered as sterile. I find that the knowledge of many of my colleagues is just as limited. It has always appeared to me somewhat strange that we should accept dressings as bacteriologically sterile merely because they have been treated in a high-pressure sterilizer. Under the present methods in vogue there is no proof whatsoever that such dressings are sterile.

Some Disturbing Facts

Inspection of six large hospitals revealed many disturbing facts, illustrating the haphazard methods in use. It is assumed that the methods of six different hospitals, each under separate administration, may be taken as fairly representative. A few examples are as follows:

1. All the surgeons were convinced that their dressings were sterile, even though they had no knowledge of the details of the technique of sterilization.
2. In only one case was there any real supervision by a sister. The packing of the drums was performed chiefly by probationers, in one instance of one month's seniority. The actual sterilizing was done either by a staff nurse or by a subordinate who could not be classed as responsible.
3. In one hospital the steam inside the sterilizer was raised to a pressure of 20 lb. per square inch, and then the main steam supply was cut off. After twenty minutes the dressings were said to be sterilized.
4. In only one hospital were dressings intelligently packed. In all others they were simply crammed into drums or bags; at one hospital it was astonishing to see the enormous quantity of cotton-wool which had been forced into a drum.
5. In another hospital the dressings, after returning from the steam laundry, were allowed to lie on an unclean floor.
6. The knowledge displayed by all concerned was either *nil*, in which case they said, “We have been taught this way,” or else they were simply “following the manufacturers' instructions.”

Perfect sterilization should be simple. It merely consists in subjecting every part of the dressing to a certain temperature for a definite period. This period must be decided by the bacteriologist, and given the correct period of time all bacteria and spores will be destroyed.

Scope of Investigation

It was decided to investigate the following problems:

- (a) What is the temperature and the duration of that temperature required to produce bacteriologically sterile dressings, the heat being applied by means of steam under pressure?
- (b) How can it be proved that the necessary temperature is reached and maintained?
- (c) Can steam under pressure penetrate dressings with ease?
- (d) Does the type of material, the method of packing, and the type of container affect the penetration of steam?

All these questions are answered by the experiments undertaken, and an endeavour is made to lay down a definite technique under accurate control to replace what is considered to be a rule-of-thumb and inaccurate method. The great variety of results obtained by experiment indicates that the standard method of sterilization at present in general use—that is, by steam at a pressure of 15 or 20 lb. per square inch for twenty minutes—is far from accurate. (Recently some manufacturers have recommended thirty minutes.) This method is based on the assumption that steam penetrates dressings almost immediately. This is incorrect. Working with steam under pressure at a temperature of 126° C. I have found delay varying from one to seventy-two minutes in recording a temperature of 115° C.—that is, 11° C. less than that of the steam in the centre of a dressing drum. Steam under pressure should no longer be regarded as an agent that has remarkable powers of penetration. Unless certain conditions are observed it penetrates extremely poorly.

It is rarely that dressings are suspected or blamed as the cause of infection. The explanation may be due to the undoubted fact that we all have such implicit faith in a steam sterilizer, or that it is impossible ever to carry out any bacteriological tests after the infection has occurred, as by that time the dressings will have disappeared. I suggest that it is as logical and necessary to inquire into the efficiency of the sterilization of dressings as it is to swab nurses' throats or to blame the theatre sister or the catgut.

Time and Temperature

Textbooks, although insisting that sterile dressings are a necessary adjunct to successful operations, are somewhat indefinite as to the details of sterilization. Examples are “in a high-pressure steam sterilizer”; “one hour at 10 lb. (115° C.) will be sufficient” (Berkeley and Bonney, 1935); “use steam pressure” (Blair-Bell, 1934); “in a steam sterilizer” (Crossen, 1930). The information required is clearly—what is the temperature and duration required to kill all vegetative and sporing forms of bacteria? I suggest that this information should be made available and be inserted in all textbooks in which the sterilization of dressings is mentioned.

It was decided to adopt the standard used by bacteriologists when sterilizing media, etc.—that is:

1. “Fifteen minutes' exposure to steam at 15 lb. per square inch (121° C.) above atmospheric pressure will kill all forms of organisms, including the most resistant spores.” (Mackie and Macartney, 1934.)
2. “For practical purposes, from common knowledge, 115° C. for twenty minutes is invariably fatal to tetanus spores.” (Medical Research Council, 1924.)

I have adopted "an exposure to steam at a temperature of 115° C. for twenty minutes" as being sufficient to kill all bacteria and spores. This is referred to hereafter as "the standard of sterilization" (S.S.). This standard may be regarded as unduly high. It should be noted, however, that modern sterilizers are made to work with steam at a pressure of 20 lb. to the square inch (126° C.), and the manufacturers recommend exposures of from twenty to thirty minutes.

Steam under pressure has practically superseded dry sterilization and steam at atmospheric pressure. The apparatus used is a high-pressure sterilizer; the drums containing the dressings are placed inside it, and the contained moisture and air are driven off by heat or by the creation of a vacuum. Steam is now admitted into the sterilizer until the pressure rises to a height determined by the type of sterilizer. The steam enters the drums and comes into contact with each particle of dressing. Sterilizers are manufactured to work at various steam pressures; these are chiefly:

1. 10 lb. sq. inch corresponding to a temperature of 115° C.
2. 15 lb. sq. inch " " " " 121° C.
3. 20 lb. sq. inch " " " " 126° C.

Methods of Control

A control which should indicate when a temperature of 115° C. has been reached and maintained in the centre of a drum for twenty minutes is necessary. The present methods of control in use are:

1. A recording apparatus, fitted to the sterilizer, which records in graph form the pressure and duration of steam inside the sterilizer. It is of no practical value, as it gives no indication whatsoever of the temperature *inside* the drums.
2. Flowers of sulphur.
3. Fusible alloys.

These are placed inside a drum; they melt at a certain temperature. As they indicate only that a temperature has been reached and maintained for the short time necessary to produce melting they are of no value as an indicator for a duration of twenty minutes.

4. Small glass control tubes containing a chemical which changes colour when exposed to a certain temperature for a particular period. In one such control a colorimetric chart is supplied showing the various colours produced by heat, together with the relative temperature and duration. A tube is placed in the centre of the dressing drum, and after sterilization the colour is compared with the chart.

My preliminary experiments were made with glass control tubes. They appeared ideal, as according to the instructions "one of these tubes placed in a batch of dressings before steaming will indicate both the temperature and its duration." One hundred and fifty experiments were made on seven sterilizers, with such conflicting results that I had the tubes tested for accuracy. It was found that under laboratory conditions the makers' statements could not be substantiated, and this method of control was abandoned as not being able to indicate correctly the accurate "Standard of Sterilization." The experiments made are not published.

An accurate method of control with the following properties was sought: it must (a) accurately indicate when a temperature of 115° C. has been reached (allowing an error of $\pm 1^\circ$ C.); (b) be of simple construction; (c) be easy to test for accuracy; (d) be easy to replace; (e) be capable of being used by a person of low intelligence; (f) be of low cost. The instrument devised by Dr. Suri and myself and shown in Fig. 1 fulfils all these conditions.

It consists of a mercury thermometer into the lumen of which are fused two platinum points—the upper at 115° C. The thermometer is placed in a bakelite and metal case. The platinum points are attached to two terminals on the case. A rise of the mercury in the lumen causes contact to be made between the two platinum points. The sterilizer lid or door is fitted with two insulated terminals, and an indicator system consisting of a dry battery or main electric supply with transformer, lamp, or lamp and bell, with on and off switches.

This control is placed in the centre of the dressing drum, and two special wires, capable of withstanding high temperatures, are connected to its terminals and the terminals inside the sterilizer door. The indicator system is linked up by ordinary wire flex to the terminals outside the sterilizer door. The sterilizing

FIG. 1.—Sterilizer Control.

process is begun, and when the temperature at the site where the control is situated reaches 115° C. the lamp and/or bell lights, and/or rings. The control was tested before use and was found to be accurate. It provides a simple method of ascertaining what is happening inside a dressing drum, and by its use the process of sterilization can be made to conform to the rules of the bacteriologist. It provides absolute safety and checks the efficiency of the sterilizer, including the pressure gauges.

Experiments on Steam Penetration

In each experiment the bulb of the electrical control was placed in the centre of the drum of dressings to be tested. The experiments have been carried out in groups—each group being a set problem; in each group the effect of steam on loosely and tightly packed dressings is compared.

The zero line (0) on the charts indicates when the steam pressure inside the sterilizer chamber reached 20 lb. per square inch. The dots above this line show the time taken—by each drum—for a temperature of 115° C. to be reached in the centre of the dressings. If the standard of sterilization laid down is accepted, then sterilization

begins from this point, and twenty minutes must be added in each experiment.

1. *Can Steam under Pressure Penetrate Dressings with Ease?*—According to the standard of sterilization (S.S.) adopted, sterilization begins when the temperature reaches 115° C., and continues for twenty minutes. Reference to the group experiments will show that the times taken to reach 115° C. varies considerably. To each experiment twenty minutes must be added if the standard adopted is to be observed. Out of seventy-four described experiments in only nineteen did the steam penetrate rapidly—that is, to reach 115° C. the time taken was from *nil* to four minutes. In the remaining fifty-five experiments the time taken to reach 115° C. varied from five to seventy-two minutes. It is clear that steam is not a powerful penetrator.

2. *Does the Type of Material Affect the Penetration of Steam?*—Four types of dressings have been tested. Closely woven materials such as abdominal sheets and towels are more resistant than loosely woven materials such as wool and gauze.

3. *Does the Method of Packing Affect the Penetration of Steam?*—The group experiments definitely show that tight packing hinders the penetration of steam.

GROUP I.—An experiment to show the degree of penetration of steam, using round, perforated drums. L.W.H. sterilizer, high pressure, non-vacuum, working at 20 lb. per square inch (126° C.); drums—round, perforated; sterilizer—loosely packed with twenty-five drums. 0 = the time when the steam pressure inside the sterilizer reached 20 lb. per square inch (126° C.).

4. *Does the Type of Container Affect the Penetration of Steam?*—Black (1935) states: "It is just as easy for superheated steam to penetrate a non-perforated drum (with the lid open) as a perforated drum," and advocates the use of unperforated drums as being efficient and cheap. The large majority of sterilizers, however, use dry, saturated, or moist steam, and even when superheated steam is available the degree of superheat is not high. The comparative experiments in Groups II and III indicate very clearly that the penetration of steam through dressings in unperforated drums is extremely slow and inefficient. For example, to efficiently sterilize six abdominal sheets, according to the standard laid down, in an unperforated drum would take 72 + 80 minutes (Group II Exp.). To sterilize the same material in a similar drum perforated would take 10 + 20 minutes (Group III Exp.). This is a marked difference, and is worthy of note as unperforated drums and tins are in common use.

A careful study of Groups I, II, and III experiments is recommended to those who use unperforated drums and dressings in hermetically sealed tins, obtained from

commercial houses for private operations. Non-perforated drums used without an efficient control appear to be definitely dangerous.

GROUP II.—An experiment to show the degree of penetration of steam, using square, unperforated drums. Sterilizer as in Group I; drums—square, unperforated, 10 inches by 8 inches by 9 inches; lid opened during sterilization. 0 = the time when the steam pressure inside the sterilizer reached 20 lb. per square inch (126° C.).

GROUP III.—An experiment to show the degree of penetration of steam, using square drums with perforations at both ends. Sterilizer as in Group I; drums—square, 10 inches by 8 inches by 9 inches; type as used in Group II, but with both ends perforated. 0 = the time when the steam pressure inside the sterilizer reached 20 lb. per square inch (126° C.).

Vacuum and Non-vacuum Sterilizers

The most expensive sterilizers are fitted with a vacuum-producing mechanism. The principle involved is that a vacuum is first produced inside the sterilizer, thus withdrawing all air and moisture from the dressings. Steam is then admitted, and as there is a negative pressure, rushes into the interstices of the dressings.

showed again that the tight packing of a sterilizer is a dangerous practice, and it emphasizes, too, the value of a control.

Technique of Dressing Sterilization

As so many factors can influence the efficiency of sterilization, the processes of packing drums and of sterilization should be considered as requiring a definite technique and adequate supervision.

GROUP IV.—Experiments to test the efficiency of vacuum and non-vacuum sterilizers. 0 = the time when the steam pressure inside the sterilizer reached 20 lb. per square inch (126° C.).

Theoretically, therefore, more efficient penetration is produced by a vacuum sterilizer. Experiments were conducted with a sterilizer of similar size to that used in Group I, except that a vacuum apparatus was fitted. The vacuum had no apparent effect in assisting penetration. Further experiments with vacuum sterilizers are shown in the Group IV chart, and these indicate that the large vacuum sterilizer has no superiority over the non-vacuum type. As the number of experiments made on vacuum and non-vacuum sterilizers is small, no dogmatic conclusion can be drawn, but it may be pointed out that whether a vacuum is or is not used, an efficient method of control is still necessary. A vacuum can give no extra measure of safety without efficient control.

Group V experiments compare the efficiency of five different sterilizers. The time to reach the temperature when sterilization begins varies from one to nineteen minutes. This again proves the futility of sterilizing for a standard time without control. In tests to find whether a vacuum sterilizer was of greater value when its action was prolonged experiments indicated that in a large sterilizer prolongation of the vacuum action did produce increased efficiency, but prolongation of the time was of no value in small sterilizers.

Further experiments tested the efficiency of khaki-drill bags as containers for dressings. They appeared to be moderately efficient providing that the sterilizer was packed loosely. If, however, the sterilizer was packed tightly they were definitely inefficient. This experiment

1. Perforated drums should be used.
2. Each drum should be filled in a definite manner, which should never be varied. The contents of the drum should

GROUP V.—Experiments to compare the efficiency of five different sterilizers, using the same control drum, which contained thirteen towels and was unopened throughout, 0 = the time when the steam pressure inside the sterilizer reached 20 lb. per square inch (126° C.).

then be marked on a label attached to the drum. All articles should be *loosely rolled* and placed end on in the drum.

N.B.—Cotton-wool, before packing, should be unrolled and exposed to heat. It will then swell to twice its original thickness.

Great care should be taken to pack the drum lightly.

3. The sterilizer should be fitted with a control of the type described.

4. With the control in the centre of the drum, each drum should then be tested in order to ascertain the time taken for 115° C. to be reached. This time should be recorded on the drum label.

5. When sterilizing the control should always be inserted into the drum of dressings which are the most resistant to steam—as indicated by the time taken to reach 115° C.

6. Supervision by a responsible member of the nursing staff is necessary to (a) see that all drum perforations are open before sterilizing begins; (b) see that the perforations

3. A simple control has been devised which accurately indicates when the sterilizing temperature is reached *inside* a dressing drum.

4. Experiments were first made on seven high-pressure sterilizers of different types, using a liquid control. These experiments are not published as it was considered that the control was not accurate. The results in general showed that sterilization was inefficient.

5. Further experiments were made, using the electric control described on four different types of sterilizer. The conclusion is that present-day methods of sterilization are inefficient unless a definite technique is adopted.

6. Steam under pressure is not considered as having remarkably efficient powers of penetration.

7. Carelessly packed drums, unperforated drums, and tightly packed sterilizers have been shown to obstruct the penetration of steam.

8. A technique of sterilization has been suggested and the necessity for an adequate control indicated.

GROUP VI.—Experiments to show the degree of penetration of steam, using drums packed according to the technique described, and as used in this hospital. L.W.H. sterilizer, as in Group I. The drums are described as large (L), medium (M), and small (S). 0 = the time when the steam pressure inside the sterilizer reached 20 lb. per square inch (126° C.).

are closed immediately after sterilization; (c) see that a temperature of 115° C. is maintained for at least twenty minutes; (d) see that the contents of the drums never vary from the optimum found by previous testing, and that the packing is according to instructions.

Note.—To be strictly accurate, each drum should contain a temperature control; this is not practicable, and it is thus impossible to obviate the human element which might easily result in drums being improperly packed. To overcome this it is suggested that over and above the precaution advised in paragraph 5 above, the time of sterilization should be increased by 50 per cent.

The Group VI experiments show the degree of penetration of steam through drums packed according to the standard technique described above. The uniformity of penetration is in marked contrast to that shown in the previous experiments.

NOTE ON STERILIZER CONTROL

The control can be obtained from Messrs Negretti and Zambra, High Holborn, London. Insulated terminals for the sterilizer door or lid can be fitted by any engineer. The wires connecting the thermometer to the inside terminals should be heavily insulated and covered with silk. The outside connexions and indicator board can be made by any electrician.

Summary

1. Experiments have been made to ascertain whether present-day methods of sterilizing dressings are efficient.

2. A "standard of sterilization" necessary to produce bacteriologically sterile dressings has been adopted.

9. It is suggested that imperfectly sterilized dressings are a likely cause of unexplained wound infections and epidemic and sporadic puerperal sepsis.

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On the occasion of the International Congress of Ophthalmology to be held at Cairo from December 8 to 15, 1937, several trips in the Orient have been organized under the auspices of the International Council of Ophthalmology, leaving Marseilles on December 3. The programme giving full particulars of these trips will be sent free of charge on request addressed to the Bureau des Croisières et Voyages Medicaux, 29, Boulevard Adolphe Max, Bruxelles, Belgium. Doctors who are not ophthalmologists may up to the limit of accommodation available register their names for any of the trips, so long as their applications are approved by the International Council of Ophthalmology, though they will not be able to take part in the special work of the congress.