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SYRINGE NEEDLES AND MASS INOCULATION TECHNIQUE

BY

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Much attention has been paid to the sterilization of syringes and needles for mass inoculation, as there have been occasions when carelessness or faulty methods have resulted in serious transfer of infection. If large numbers of men have to be inoculated the procedure must be one that can be performed rapidly, and a committee of the Medical Research Council in 1945 issued a report in which they recommended the changing of the needle for a fresh sterile one after each injection.

Evidence of Syringe Contamination

Hughes (1946), however, when he removed the needle after intramuscular injection of patients, was able to find red blood corpuscles in the fluid on the syringe nozzle in a considerable number of cases. More recently Evans and Spooner (1950) found that, when they contaminated the needle by injection into a heavily infected animal or a broth culture of bacteria and then removed the needle, the fluid in the syringe was often infected. These observers suggested that the contamination of the syringe was due to a negative pressure induced by the removal of the needle, fluid from the distal end being sucked up on to the syringe nozzle.

We have confirmed these findings in two ways. One was to fill a syringe with broth, dip the needle about $\frac{1}{4}$ in. (0.6 cm.) into a broth culture of staphylococcus or other organism, remove the needle, and expel the broth into a test-tube, which was incubated. In most of the trials the organism into which the needle had been dipped grew in the broth. An even simpler method was to dip the point of the needle momentarily into a 1% solution of methyl violet and then remove it from the syringe. In most cases the dye could be seen in the fluid on the nozzle of the syringe.

Having convinced ourselves that the method of changing the needle between each patient is a dangerous one, we sought for a safe substitute.

Efficacy of Hot-oil Sterilization

One of us (A. F.) worked with Sir Almroth Wright for many years and had always used hot-oil sterilization for syringes and needles. It was known from long experi-

ence that it was effective in practice, but no experimental results were available. In this paper we present experimental evidence of the efficacy of this method of sterilizing needles.

Apparatus.—The oil bath used in these experiments was the type made by R. B. Turner and Co. This consists of a metal beaker filled with liquid paraffin supported by a conical metal holder and heated by a small adjustable gas jet. A thermometer which records from 100 to 200° C. dips into the oil. Thermostatically controlled models are available, but a satisfactory apparatus can easily be made cheaply from the simplest materials.

Method.—In the following experiments the infected needle has been dipped in the hot oil to a distance about half-way up the needle mount, without detaching the needle from the syringe. Almost immediately after the needle is in the oil a gush of steam escapes from the bevel. Presumably the thin shaft of the needle heats up very rapidly, and water in the lumen boils almost at once. A few seconds later another gush of steam bubbles from the needle, presumably owing to boiling of the fluid in the wider and thicker mount, as this part takes longer to heat up. These effects are shown most clearly when the temperature used is above 140° C.

The hot-oil method of sterilizing needles has three main mechanisms: (1) the actual temperature of the oil; (2) the sterilizing effect of the steam produced by the boiling of water inside the needle; and (3) the mechanical effect of the jet of steam forcing out infective material.

Time Required to Sterilize Infected Needles at Different Temperatures

A syringe was filled with 2 ml. of glucose broth and 1 ml. was ejected into a sterile tube for incubation overnight as a control to test the sterility of the syringe and needle at the beginning of the experiment. The needle was then dipped into a broth culture of an organism. A drop or two of glucose broth from the syringe was ejected into the culture, and the needle, still with syringe attached, was removed from the culture and dipped in

the hot oil for a given time. The remaining glucose broth was then ejected into another sterile tube for incubation overnight. If immersion in the hot oil had failed to sterilize the needle, growth occurred in this tube.

The test organisms were *Staphylococcus aureus*, *B. friedländeri*, *Bact. coli*, and an enterococcus which survived after heating to 60° C. for 50 minutes.

TABLE I.—Time Required to Sterilize Infected Needles in Hot Oil

Temperature of Oil Bath	No. of Tests	Time Taken to Sterilize (Seconds)
150–180° C.	6	1, 1, 1, 1, 1, 1
135–145° C.	8	1, 1, 1, 1, 1, 3, 1, 1
130° C.	10	3, 1, 3, 1, 1, 1, 1, 1, 1, 1
120–125° C.	5	1, 1, 1, 1, 3

The results are given in Table I, from which it will be seen that in all cases where the time of immersion in oil at temperatures between 120 and 180° C. was more than three seconds sterilization was obtained. In most cases no growth occurred even after dipping in oil for only one second. These results contrast with those obtained by changing the needles, where in most cases the broth in the syringe became contaminated.

It might be argued, however, that the mere dipping of the needle into a broth culture is not a sufficiently severe test. We therefore carried out a series of tests with the inside of the needle more heavily infected than could ever occur in practice.

All details were the same as in the previous experiment except for the method of infection of the needle. A wire stylet, heavily coated with a culture scraped off the surface of an agar plate, was pushed about half-way up the lumen of the needle. In most cases the agar culture was mixed with two or three drops of horse blood, as it was felt that the presence of animal protein would make the test even more severe. The needle was dipped in hot oil as before and then the glucose broth was expelled and incubated. The results (Table II) show that, even using the heat-resistant enterococcus in blood, sterilization was obtained when the needle was dipped in oil at 130° C. for more than three seconds.

TABLE II.—Time Required to Sterilize Very Heavily Infected Needles in Hot Oil

Experiment	Infective Agent Smeared on Stylet	Temp. of Oil Bath (° C.)	Time in Seconds						
			10	5	4	3	2	1	0 Control
1	Staph. aureus Heat-resistant enterococcus and horse blood	135	—	—	—	—	—	—	+
2		128	—	—	—	—	—	—	+
3		130	—	—	—	+	+	+	+
4		130	—	—	—	—	—	—	+
5		130	—	—	—	—	+	+	+

— = No growth, + = growth, in tube of broth ejected after dipping in hot oil for time stated.

Except where otherwise stated, we have used No. 12 hypodermic needles throughout. Similar experiments have also been carried out with No. 16 and No. 1 hypodermic needles and a size 0 serum needle, and essentially the same results have been obtained in all cases.

Sterilization of Needle Heavily Infected Throughout the Greater Part of its Length

An attempt was made to determine how far along the needle infective material could be deposited and still allow of sterilization by dipping in hot oil. This was done by pushing a wire stylet coated with *Staph. aureus*

to various known distances along the centre of the needle as in the previous experiment. The needle was then dipped in the oil bath at 130° C. for 10 seconds and the glucose broth expelled and incubated as before. The results were as follows.

Distance Stylet Pushed up Inside of Needle	Needle in Oil 130° C. for 10 sec. Then Glucose Broth Incubated Overnight
8 mm.	No growth
11 "	"
18 "	"
19 "	"
22 "	"
25 "	"

Length of needle used, 28 mm. (from tip of needle mount to centre of bevel of needle).

Further experiments of this kind have shown that sterilization by oil at 130° C. for 10 seconds cannot be relied upon when the inside of the needle is infected to any point beyond the shaft.

The experiment shows that infection along almost the whole of the shaft of the needle can be successfully combated by dipping in oil at 130° C. for 10 seconds.

Sterilization of Needle by Immersion in Boiling Water

In actual practice there may be times when hot oil is not easily available, so we made some observations on the rate of sterilization of infected syringe needles when they were dipped in boiling water in an open saucepan. The technique was exactly the same as in the experiments with oil sterilization, and the results were very similar. Immersion of the infected needle in boiling water for one to two seconds sometimes sterilized it; immersion for three seconds always sterilized it even when the heat-resistant enterococcus was used as a test organism.

Frequency of Contamination of Needle with Body Fluids in Process of Subcutaneous Injection in Man

We attempted to see how often body fluids could be found in the syringe needle after a simple subcutaneous injection in man. We used an anti-human-precipitin serum which gave a definite ring when a dilution of 1/2000 human serum was layered on it.

In the clinic a series of patients were receiving injections of vaccine. An extra volume of 0.2 ml. of vaccine was taken into a Record syringe, the patient received his dose, the needle was withdrawn, and the extra 0.2 ml. was expelled through the needle into a tube for test. This fluid washed out any serum that was in the needle, and if there was as much as 0.0001 ml. of serum present it could be found by the precipitin test.

Out of 50 observations human serum could be detected in six cases. Of the six fluids giving positive precipitin reactions, five showed red corpuscles when examined microscopically. This proportion agrees well with the findings of Hughes (1950), who found red corpuscles in the fluid in the nozzle of Record syringes in 14% of cases after intramuscular injection followed by removal of the needle.

A second series was done in exactly the same way except that immediately the needle was withdrawn from the patient it was immersed in oil at 140° C. for a few seconds and then the excess fluid was expelled and tested. All the results in 50 cases were negative, showing that any body fluid that had entered the needle had been destroyed or expelled by immersion in the hot oil.

Infection of Syringe after Injection against Different Pressures

A further series of experiments was carried out to determine the effect of injection against known pressures. The method was similar to that of Evans and Spooner using the "artificial mouse." This merely consists of an L-shaped glass tube with a long vertical limb and a short horizontal limb. Attached to the short limb is a short length of rubber tubing, the other end of which is blocked by a glass rod. By varying the height of the fluid the pressure can be altered to any desired level.

The "artificial mouse" was filled to known heights with broth cultures of various organisms, and 0.2 ml. from a syringe containing 1.2 ml. of glucose broth was injected through the rubber tubing. The needle and syringe were then withdrawn and the needle dipped in oil at 130° C. for 10 seconds. The remaining 1 ml. of glucose broth in the syringe was then ejected through the needle into a sterile tube for incubation as before. The results are shown in Table III.

TABLE III.—Pressure Which Causes Reflux of Infection into Syringe

Description of Syringe	No. of Times Tested	Lowest Pressure after which Hot Oil Failed to Sterilize
1-ml. Record. 15 needle	1	Over 10 in. (25 cm.) of broth
2-ml. Record. 12 "	14	7 in. (17.5 cm.) "
5-ml. Record. 12 "	1	9 in. (22.5 cm.) "
2-ml. all-glass. 15 "	2	6 in. (15 cm.) "
5-ml. all-glass. 12 "	8	8 in. (20 cm.) "
10-ml. all-glass. 12 "	1	Over 10 in. (25 cm.) "

We have already shown that 10 seconds' immersion in oil at 130° C. completely sterilized needles heavily infected along almost the whole length of the shaft, so that where growth occurred in this series we can assume that the infection had passed beyond the shaft.

A further series of experiments was carried out using an "artificial mouse" filled with a strong solution of methylene blue. A syringe filled with water was used to inject small amounts into the "mouse" and the barrel was observed for 5–10 seconds to see if there was any reflux. The lowest pressure required to produce a reflux back into the syringe was determined, but it soon became apparent that variations in the angle at which the syringe was held gave widely varying results. Table IV shows the effect of variations in the angle of entry of the syringe.

TABLE IV.—Influence of Position of Syringe on Pressure Causing Reflux

Type of Syringe	Pressure at which Reflux was Observed	
	Syringe Held 30° Above Horizontal	Syringe Held Horizontally
5 ml. all glass	3½ in. (8.8 cm.) of water	2 in. (5 cm.) of water
5 " " "	4 " (10 cm.) " "	1½ " (3.8 cm.) " "
5 " " "	4½ " (10.8 cm.) " "	2 " (5 cm.) " "
5 " " "	6 " (15 cm.) " "	2½ " (6.5 cm.) " "
5 " " "	4 " (10 cm.) " "	2½ " (6.5 cm.) " "
2-ml. Record	15½ " (39.4 cm.) " "	12½ " (31.8 cm.) " "
2 " "	Over 16 in. (40 cm.) " "	15½ " (4 cm.) " "
2 " "	1 in. (2.5 cm.) " "	½ " (1.9 cm.) " "

No. 12 needle used in all cases.

There was a considerable difference between individual syringes and even in the same syringe according to the position of the plunger. In one instance, using a 2 ml. Record syringe, there was no reflux of methylene blue up to a pressure of 10 in. (25 cm.) of water when

the plunger was at the 0.8-ml. mark, but the pressure required to produce reflux was only 1 in. (2.5 cm.) of water with the plunger at the 2-ml. mark. This, of course, is an illustration of the lack of uniformity of bore of a syringe barrel.

The pressures required to produce reflux, using the method with methylene blue, are lower than might be expected from the experiments using broth cultures. This is probably because the needle was left in the "artificial mouse" for 5–10 seconds using the methylene blue, whereas for the broth cultures the time the needle was left in was only of the order of 1–2 seconds.

Can Reflux into the Syringe be Prevented?

In the previous experiments no attempt was made to control the piston, and in view of the variability of the pressure required to cause reflux into the syringe another technique has been tried. Any method of giving multiple injections from one filling of the same syringe is open to criticism, as the smallest plunger movements may allow of back flow into the syringe.

If, however, the syringe contains only one dose, at the end of the injection the plunger would be firmly pressed against the bottom of the syringe, and this pressure could be maintained while the needle is being withdrawn. This should prevent any reflux into the syringe. In order to test the effectiveness of this method further experiments were carried out.

An "artificial mouse" filled with a broth culture of *Staph. aureus* was connected with an apparatus for raising the pressure considerably. A sterile 2-ml. Record syringe with a No. 12 needle was filled with 0.2 ml. of glucose broth, and the whole of this was injected through the rubber, keeping the plunger firmly "home" until the needle was withdrawn. The needle was then dipped in oil at 130° C. for 10 seconds, after which 1 ml. of glucose broth was aspirated into the syringe and ejected into a sterile tube for incubation as before, to determine if sterility had been attained. The pressures used were equal to 1, 2, 3, 5, 7, 10, 12, and 20 feet (0.3, 0.6, 0.9, 1.5, 2.1, 3, 3.7, and 6.1 metres) of water, and sterility was obtained every time when injections were done against these pressures.

The results obtained with this technique, even against these very high pressures, indicate that it is a sure protection against any reflux into the syringe, during or after injection, and it should be an effective means of preventing infection being carried from one patient to another.

It is, in fact, a method which has been in use in this institute for a long time, and by it injections can be carried out rapidly and safely.

Discussion

In mass inoculation it has been common practice, following the advice given in the M.R.C. Memorandum, to change the needle between each inoculation. The work of Hughes and of Evans and Spooner has shown that, although this method provides a sterile needle for the next patient, the changing of the needle often leads to the contamination of the fluid in the syringe. The next patient therefore may receive a contaminated fluid through a sterile needle, which is obviously bad practice.

It is sometimes maintained that the risk of infecting the second patient is so small that the method is worth while because of its convenience and rapidity. In this

connexion we must consider Hughes's findings (which we have confirmed by another method) that in something like 14% of cases, after inoculations into man with a Record syringe, some body fluid enters the needle and can be transferred to the syringe in the process of changing the needle.

The amount of body fluid gaining access to the needle may be very small, and in the vast majority of cases it would not be infected. The potential danger, however, remains, and clearly the method of changing needles should be discarded, especially if one equally convenient can be substituted.

We have shown that, without removing them from the syringe, needles can easily and quickly be sterilized by immersion for 10 seconds in liquid paraffin at a temperature of 130° C. or over. If the oil is to be used only to sterilize needles then it might be heated to about 150° C., which obviously gives a greater margin of safety, although we have shown that at 130° C. sterilization is complete in three seconds or less.

If hot oil is not obtainable, immersion of the needle for 10 seconds in boiling water is effective. Oil is preferable, as the needles remain sharp for a longer time and do not rust.

In mass inoculation there is a second problem to be considered—namely, the possibility of reflux of fluid from the body of the inoculated man beyond the needle into the syringe. When multiple doses are given from one filling of the syringe, it is very difficult to be certain that in the course of the series of inoculations some accidental movement of the piston of the syringe does not occur. Quite apart from the possibility that there might be sufficient pressure in the tissues to cause reflux of the fluid into the syringe, any movement of the piston might easily draw a small quantity of fluid back through the needle. There is therefore a possibility of danger in this method of taking up into the syringe a number of doses and giving them one after another to different people, however thoroughly the needle is sterilized.

We have provided evidence that if only one dose is taken up into the syringe, and after inoculation pressure is kept up on the piston until the needle is withdrawn, there is no reflux of fluid into the syringe even when the injection is made against pressures enormously greater than could possibly obtain in the body.

This method of inoculating, combined with sterilization of the needle by 10 seconds' immersion in oil at over 130° C., seems to offer a method which is perfectly safe and which is rapid enough for mass inoculation.

REFERENCES

- Evans, R. J., and Spooner, E. T. C. (1950). *British Medical Journal*, 2, 185.
 Hughes, R. R. (1946). *Ibid.*, 2, 685.
 — (1950). *Ibid.*, 2, 366.
 Medical Research Council (1945). War Memorandum No. 15, "The Sterilization, Use, and Care of Syringes." H.M.S.O., London.

POST-GASTRECTOMY SYNDROMES

A STUDY IN APPLIED PHYSIOLOGY

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Gastrectomy is a good and safe operation for the relief of peptic ulceration. The mortality is less than 2% in capable hands, and over 90% of the patients are well and lastingly satisfied. The results of various forms of gastrectomy for carcinoma of the stomach and oesophagus are steadily improving. We are concerned here, not with the vanishing problem of recurrent ulceration or with recurrence of growth, but with those other sequelae of operation which collectively are known as the "post-gastrectomy syndromes." We believe that they all result from, and can be understood in terms of, the alterations in alimentary physiology which follow operations on the stomach. The more we study these conditions the more we are able to see a coherent pattern into which the different pieces can be fitted. We have studied in detail some 300 patients who have undergone gastrectomies of various types, and many of them have been seen repeatedly and fully investigated. A fair proportion of them have been "problem patients" who have been referred to us. We have not studied in detail the effects of gastro-entrostomy or of vagotomy, but shall refer to them in so far as they throw light on the problems of gastrectomy.

Normal Physiology*

A knowledge of the normal physiology of the stomach is essential to an understanding of the effects of the various operations. It may be considered under four headings (Fig. 1).

1. *Reservoir Function of Stomach: Gastric Emptying.*—The main function of the stomach seems to be the preparation of food for the small intestine, in which most of the digestion and absorption occurs. Food is mixed, diluted with gastric juice, and converted by churning peristaltic movements of the pyloric end of the stomach into liquid chyme, which is passed at a suitable rate through the pylorus and into the duodenum. The rate at which the stomach empties depends on the difference in pressure on the gastric and duodenal sides of the pylorus, and this is regulated by various factors. Thus the presence of hydrochloric acid or of products of protein digestion in the duodenum delays the rate of gastric emptying by a reflex mechanism which involves the vagi. Fat and carbohydrate in the duodenum stimulate the production of enterogastrone, which delays gastric emptying by a humoral mechanism. Hypertonic solutions of sugar, protein digests, etc., which are formed from food, are rapidly diluted in the stomach, so that they are isotonic by the time they reach the jejunum. Gastric movements and tone are normally under the control of the vagus nerves.

2. *Secretion of Hydrochloric Acid.*—HCl is secreted by the oxyntic cells, most of which are found in the body of

*In the anatomical nomenclature we have followed the British Revision (1933) of the B.N.A. (Gray, 1935). Confusion exists because many authors still refer to the "body" of the stomach as the "fundus" and to the "fundus" of the stomach as the "cardia."

According to a recent news report in the *New York Times*, Dr. J. E. Smith, of the United States Civil Aeronautics Administration, has invented an instrument which records the heart beat, quite literally. That is to say, it is a miniature seismograph which is strapped across the patient's shins and records the vibration in the body from each beat. The ballistocardiograph has been in diagnostic use for some time, but Dr. Smith's apparatus is apparently an improved version and works in conjunction with an electrocardiograph.