THE REMOVAL OF AIR DURING AUTOCLAVE STERILISATION OF FABRICS USING LOW PRESSURE STEAM

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A modified sterilising cycle has been evolved after studying the temperature distribution and effects of moisture in fabrics in the pre-sterilisation phase. A vacuum of 20 mm. Hg abs. followed by the introduction of steam to raise the pressure to about 200 mm. abs. and then re-applying a vacuum of 20 mm. Hg abs. was found to produce the required conditions to give even heating throughout the materials.

Removing air from the interstices of fabrics by downward displacement is a protracted and uncertain procedure. Evacuating to about 200 mm. Hg abs., introducing steam to above atmospheric pressure and re-evacuating to the same vacuum before introducing steam for the sterilising period removes more air but this procedure is unreliable (Savage, 1937; Perkins, 1956; Alder and Gillespie, 1957). Evacuating the chamber and dressings to below 20 mm. Hg abs. (B.S. 3220/1960) produces accepted sterilising conditions within the chamber but it is now doubted whether these conditions are always obtained within woven fabrics such as towels and gowns. The work upon which this cycle was based (Knox and Penikett, 1958) took no account of the moisture content of the dressings but the relation of moisture and superheating has since been discussed (Henry, 1959).

Previously the importance of the moisture content of dressings undergoing sterilisation by downward displacement has been commented upon (Barson, Peacock, Robins and Wilkinson, 1958) and a more critical examination of the high preliminary vacuum sterilising cycle has now been made. We report the influence of the moisture content and temperature of dressings on the reliability of sterilisation when high preliminary vacuum is employed and also a means of improving the reliability of dressing sterilisers.

Experimental and Results

Two autoclaves were used; autoclave A, and its recording apparatus, have been described (Barson, Peacock, Robins and Wilkinson, 1958). Autoclave B was jacketed, rectangular, 92 × 66 × 132 cm. deep, built to B.S. 1500/1960 and fitted with automatic control to B.S. 3220/1960 as well as manual control. Modifications were made to introduce steam for a period during stage 1 of the automatic cycle and for the cycle to be continued after the normal automatically controlled period had elapsed.

We chose 135° (equivalent to steam at 2·11 kg./cm.^{2} gauge) as the experimental temperature, which would need a sterilisation time of 3 min. (M.R.C. Working Party Report, 1960). Thirty huckaback towels, 56 × 76 cm., were folded and packed into a dressing casket, 28 × 28 × 25

cm. deep, so that the folds were in a vertical plane. They were allowed to equilibrate with atmospheric conditions. In this condition they contained 6 to 7 per cent of moisture. The dressing drum was positioned in the centre of autoclave A with a thermocouple near the geometrical centre of the pack. The autoclave was evacuated to 20 mm. Hg abs., steam introduced to 2·11 kg./cm.^{2} gauge (30 p.s.i.g.) for a pre-determined period. In 30 replicate experiments where the temperature at the centre of the pack was compared with the drain temperature, the centre of the pack took between 0 and 15 min. to attain the same temperature as the drain (Fig. 1). In a subsequent 20 experiments, 3 thermocouples were arranged vertically separated from one another by about 2 cm. in the centre of the pack. In all experiments some thermocouples were slow to

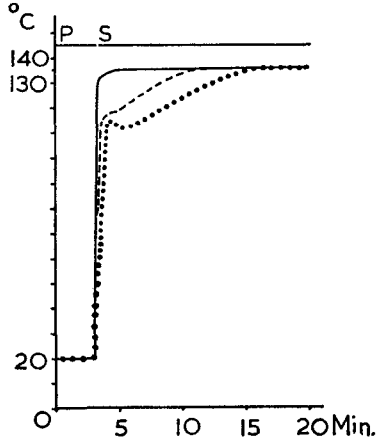

FIG. 1. Normal BS.3220/1960 Cycle (manually extended).

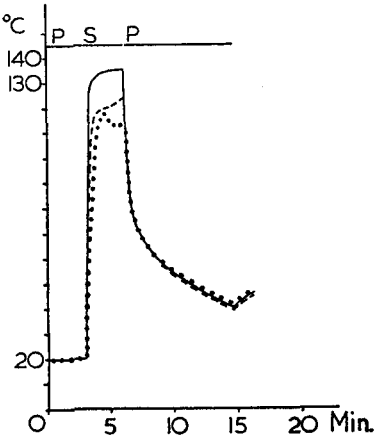

FIG. 2. Normal BS.3220/1960 Cycle (automatic).

Key to Figs. 1, 2, 3 and 4. —— Chamber and upper position in casket. – – – Median position in casket. · · · · · Lower position in casket. P—Pumping period. S—Steaming period.

reach chamber temperature and it was impossible to predict which position would be the slowest. With 5 thermocouples similarly disposed the effect was more noticeable and the random distribution confirmed in 20 replicate experiments.

In autoclave B, using manual control, the experiments were repeated more than 30 times and the random distribution confirmed. With automatic control (B.S. 3220/1960) some thermocouples did not attain the experimental temperature (Fig. 2) and spore papers positioned close to these thermocouples were not sterilised. Similar results were obtained in experiments using ten replicates when the packs were initially heated to 40° and 50°.

The moisture content of packs was adjusted by adding water to fabrics previously dried to constant weight at 100 to 105°, allowing them to equilibrate in a closed container and re-weighing immediately before positioning in the autoclave. The moisture content was calculated as

a percentage of dry weight. Replicate series of experiments were made using fabrics containing less than 5 per cent, 11 to 12 per cent, 20 per cent and 40 per cent of moisture and the results obtained were similar to those using air dried fabrics.

Further experiments were made using only 20 towels within the casket, but although the temperature range within the casket was reduced a distribution still existed.

The temperature distribution was smallest in experiments where the temperature of the fabrics fell during the preliminary vacuum stage. To examine this effect further, pumping was continued for up to 20 min. after 20 mm. Hg abs. pressure had been reached, during which time the pressure fell to about 6 mm. Hg abs. and the temperature of the fabrics

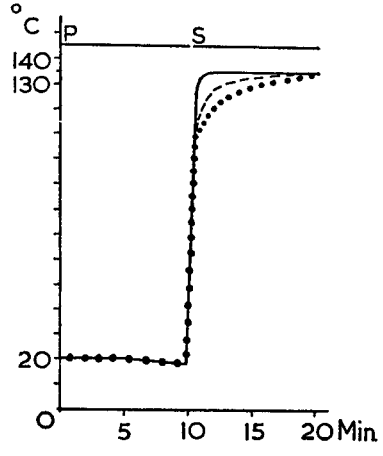

FIG. 3. Cycle using extended preliminary vacuum. See Fig. 1 for key.

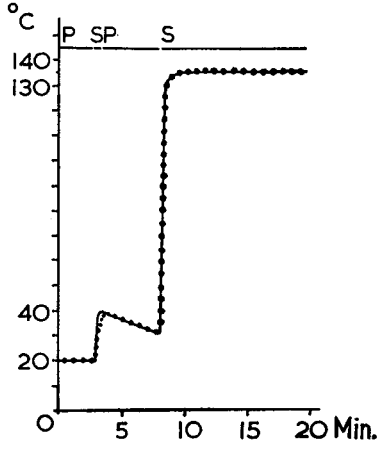

FIG. 4. Cycle with steam injection during the preliminary vacuum stage. See Fig. 1 for key.

dropped to about 19°. When steam was introduced the temperatures reached within the pack after the sterilising time of 3 min. showed less range, but were not uniform. Fig. 3, using 10 min. pumping is typical of the results for the series.

In further experiments steam was introduced into the chamber after the first vacuum, followed by re-evacuation to 20 mm. Hg abs. During this period the temperature of the pack fell and when steam was introduced for the sterilising period all thermocouples reached chamber temperature together.

The amount of steam admitted after the first evacuation was varied by increments in successive experiments so that the pressure within the chamber was increased from 20 mm. Hg. abs. to various pressure levels between 50 mm. Hg abs. and 2·11 kg./cm.^{2} gauge. It was found that an increase in pressure by means of steam to about 200 mm. abs. increased the temperature of the fabrics to 40–45° and subsequent evacuation to about 20 mm. Hg abs. cooled them to 35–40°. When steam was admitted

for the sterilising period, sterilising conditions were recorded by all thermocouples (Fig. 4). This behaviour was proved to be independent of the load or its initial moisture content. Similar experiments were conducted using autoclave B filled to capacity with fabrics in caskets and dressing drums, and repeated satisfactory time-temperature conditions suitable for sterilising were achieved in all parts of the load. This was confirmed by the use of *B. stearothermophilus* spore papers distributed throughout the load.

To challenge the method still further the slides over the apertures of the caskets were closed before being submitted to the cycle and the drums were laid so that the layers of fabric were horizontal. Thermocouples were also positioned in folded rubber sheets within these drums. In all cases the experimental temperature was reached consistently and confirmation of sterilising conditions was obtained by the use of spore papers.

The automatic cycle for autoclave B was modified so that the sequence became: evacuate to 20 mm. Hg abs., admit steam to 200 mm. Hg abs., evacuate to 20 mm. Hg abs., steam to 2·11 kg./cm.^{2} gauge for 3 min., evacuate to 40 mm. Hg abs., admit air. During the second evacuation the temperature of the fabrics fell from about 45° to under 40°, although the jacket was maintained at 135°. During the second steam period all thermocouples within the pack recorded temperatures which were contiguous with that recorded by a thermocouple in the chamber drain. Numerous replicate experiments produced similar results.

Discussion

Our experiments show that the upper portion of the pack frequently reached the same temperature as the chamber drain, while the centre portion about one-quarter from the base of the pack was usually at a lower temperature. The delay of a part in reaching chamber temperature is probably due to retained air being displaced downwards through it from the interstices above. This effect does not occur in the uppermost region because there is only steam in it. The residual air is compressed towards the centre by the incoming steam and has then to be removed by downward displacement. The inflection in the record from some thermocouples is probably due to the pocket of air being displaced past them in a downward direction.

It is evident from Figs. 1 and 2 that even at 20 mm. Hg abs., steam does not consistently penetrate to achieve sterilising conditions. This can be accounted for by the presence of residual air. When pumping was continued, as shown in Fig. 3, more consistent results were obtained from further removal of air, but there were still variations. It was noted that the best conditions were usually accompanied by a fall in temperature of the dressings during the latter stages of the preliminary vacuum period. This suggested that moisture was being removed as vapour and with it entrained air. Varying the moisture content and the initial temperature of the dressings produced no consistent cooling during the preliminary vacuum period and had no influence on the

temperatures obtained when steam was admitted to the chamber. The cooling effect was much increased after steam was admitted during the preliminary vacuum period to heat and moisten the fabrics. Irrespective of the load or method of packing, all parts of the pack reached sterilising temperature and at the same rate as the temperature of the chamber drain when this procedure was employed. We believe that this effect is due to moisture being distilled from the warmed and moistened fabrics under the influence of the vacuum, thereby displacing residual air so that steam when introduced for the sterilisation period penetrates rapidly into the interstices. Water vapour is the only constituent of the continuous phase. The amount of preliminary steaming, although not critical, varies with the load, and the fabrics should be raised to at least 40°. When this cycle is used the drain temperature is a true indication of the conditions within the dressings. Thus it has not been possible to obtain sterilising conditions consistently within packs of fabrics when employing the B.S. 3220/1960 cycle. We would therefore recommend the following cycle as an alternative to that set out in B.S. 3220/1960: evacuate to 20 mm. Hg abs., admit steam to 200 mm. Hg abs., evacuate to 20 mm. Hg abs., steam to 2·11 kg./cm.^{2} gauge for 3 min., evacuate to 40 mm. Hg. abs., admit air.

REFERENCES

Alder, V. G. and Gillespie, W. A. (1957). *J. clin. Path.*, **10**, 299–306.
Barson, T. E., Peacock, F. G., Robins, E. L. and Wilkinson, G. R. (1958). *J. Pharm. Pharmacol.*, **10**, *Suppl.*, 47*T*–59*T*.
British Standard 3220: 1960, p. 13.
British Standard 1500: 1960.
Henry, P. S. H. (1959). *J. appl. Bact.*, **22**, 159–173.
Knox, R. and Penikett, E. J. K. (1958). *Brit. med. J.*, **1**, 680–682.
M.R.C. Working Party Report, 1961, *see Lancet* (1959), **1**, 425–435.
Perkins, J. J. (1956), *Principles and Methods of Sterilization*, p. 54, London: Blackwell.
Savage, R. Maxwell (1937). *Quart. J. Pharm. Pharmacol.*, **10**, 445–450.

The paper was presented by MR. WILKINSON. The following points were made in the discussion.

Dressings kept under normal storage conditions retained sufficient moisture to allow effective sterilisation; those kept in an arid atmosphere or with 20 per cent or more of moisture were unsuitable for the procedure. Using the technique described in the paper, holding the vacuum was considered unnecessary. The caskets used were of standard design.