J. Hyg., Camb. (1979), 82, 361
With 1 plate
Printed in Great Britain

An instrument for measuring bacterial penetration through fabrics used for barrier clothing*

BY ULRIKA RANSJÖ AND ANNA HAMBRAEUS
The Institute of Clinical Bacteriology, Uppsala University, Uppsala

(*Received* 25 *April* 1978)

SUMMARY

A new instrument has been designed to measure the penetration by rubbing of bacteria from cloth contaminated in the nursing of burn patients through fabrics designed for barrier garments. Most fabrics tested dry reduced the transfer of bacteria from the source cloth to about 10 %, irrespective of the results of air filter tests, which agrees with mock nursing results. When the fabrics were tested against a wet surface, the transfer of bacteria rapidly reached 100 % if the fabrics had a high wettability, but was slower for fabrics with a low wettability. Through closely woven waterproofed cotton, transfer was 5–25 %, but increased three- to four-fold after ten launderings, in line with the water absorption. Transfer through plastic-laminated material was less than 1 %. The results suggest that barrier garments should be made either of plastic or of recently waterproofed closely woven cotton at points of contact between nurse and patient where the clothes may be wetted by bacteria-containing wound secretions.

INTRODUCTION

The efficiency of fabrics used for barrier garments can be tested in many ways. The pore size of the material can be measured optically or in a fluid chamber (Lidwell & Mackintosh, 1978). The ability of the materials to act as air filters is often measured with air suspended dusts (Hambraeus & Ransjö, 1979). Such tests do not seem to be adequate for the selection of materials as barriers against bacteria.

In experimental nursing, clothes made from materials that in particle penetration tests were 100 times more effective than loosely woven cotton, were only five times better as barrier garments (Hambraeus & Ransjö. 1977). The reason for this discrepancy might be that during nursing, bacteria are rubbed into the cloth rather than blown through it. That particles can be rubbed through textiles has been known for many years (Rubbo & Saunders, 1963; Charnley & Eftekhar, 1969). An instrument for rubbing inert particles resembling skin scales through materials has been designed (Lidwell & Mackintosh, 1978).

In clinical trials, there was no difference between the rates of infection whichever of the materials was used for the barrier garment (Ransjö, 1979). This further reduction in efficiency may be due to the fact that when nursing a patient the

* Supported by a grant from the Swedish National Defense Research Institute.

0022-1724/79/0049-1978 $01.00

nurse often comes into close contact with wet wound secretions. The fact that the properties of textiles can change when wetted is well known (Beck & Carlson, 1963) and water repellency may be of importance.

The aim of this investigation has been to find a test method that measures the penetration of bacteria through fabrics used in barrier garments. An instrument has been designed to measure the penetration of bacteria-carrying particles when rubbed into materials under both dry and wet conditions. The water absorption and electric charge propensity of the materials tested have also been investigated. The results have been compared with earlier investigations of the materials.

MATERIALS AND METHODS

The instrument (Plate 1)

RULLA, the instrument (Plate 1) built by P. Krantz, Wallenberg Laboratory, Uppsala, consists of a turntable, rotating at a speed of 60 rev./min. On the turntable, a 13·5 cm plastic Petri dish was placed, containing the sampling surface. A sterile piece of the barrier fabric to be tested, and over that the bacterial source, a piece of contaminated cotton, were stretched over the rim of the Petri dish. The pieces of fabric were kept in position by a nylon ring, fixed in a groove in the side of the turntable. A sterile teflon cylinder with a hemispherical lower end, 2 cm in diameter and weighing 24·5 g, was fixed at the end of a 27 cm long metal arm with a counterweight of 244 g at 7 cm from the other side of the pivot. The arm was moved by a rotating eccentric disk. The teflon hemisphere was pressed against the textile surface, and tracked the whole surface of the Petri dish in 15 min.

Source of bacteria-carrying particles

Green cotton fabric (Table 1) was used for operating room gowns worn in the burn unit where the previous investigations had been carried out. Pieces of such green cotton were pinned on to the front of the barrier garment worn during a morning nursing of a burn patient, and thus became contaminated with the patient's wound bacteria.

Measurements

The bacteria that had penetrated the barrier fabric tested during rubbing for 15 min in the RULLA were collected on dry or wet sampling surfaces in the Petri dish.

Dry rubbing. To test the properties of the barrier cloth when dry, the bottom of the Petri dish was covered with a 13 cm Millipore filter, pore size 0·2 μm. After sampling, the filter was placed with the sampling side up on a blood agar plate.

Wet rubbing. To test the properties of barrier materials when wetted the Petri dish contained 1 cm thick fresh blood agar.

Ten consecutive 15 min samples were taken from each source-barrier pair. After that, the same source piece was sampled again onto the same type of sampling surface without any barrier fabric. The blood agar plates, with the filters on top

Table 1. *Properties of fabrics used for barrier garments*

Fabric	Fibre	Weight/m²	Threads/10 cm	Per cent penetration of particles
Green cotton	Cotton	165	285 × 250	48·6
Ventile				
L19, washed twice	Cotton	220	330 × 230	1·9
L24, unwashed	Cotton	186	420 × 290	9·5
L32, unwashed	Cotton	137	560 × 420	23·2
Nomex	Polyamide	270	156 × 99	—
Tyvek 1443	Polyethelyne	39	Spun bonded	2·5
Klinidrape	Rayon	—	Non-woven bonded	—
Klinidrape + polyethylene laminate				

(— = not tested.)

of them after dry rubbing, were incubated at 37 °C for 48 h. The number of colonies of *S. aureus* and of total bacteria were then counted. The number of bacteria that had penetrated the barrier fabric from the contaminated cloth was measured as the ratio of the number of colonies on plates no. 1–10 to the number on plate no. 11 (Figs. 1, 2).

As a comparison, one series each in dry and wet rubbing were done without barrier material. The ratio of the number of colonies on plates 1–10 to the number

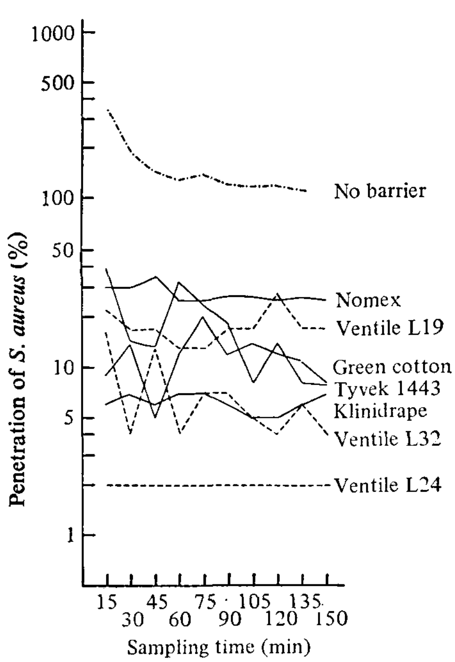

Fig. 1.

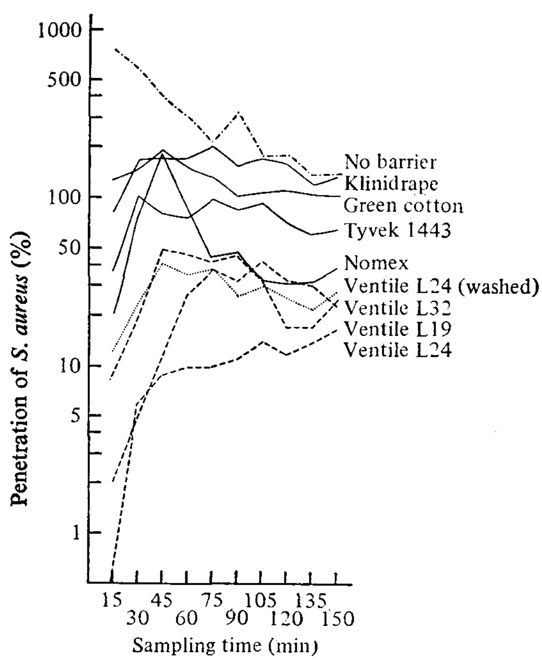

Fig. 2.

Fig. 1. Ratios of penetration of bacteria through dry fabrics.

Fig. 2. Ratios of penetration of bacteria through wetted fabrics.

https://doi.org/10.1017/S0022172400053894 Published online by Cambridge University Press

on plate 11 was given as a relative percentage in this case also (line 'no barrier' in Figs. 1 and 2).

Electric charge propensity and conductivity

Electrostatic properties of the fabrics tested were measured by a method developed at the Swedish Textile Research Institute, Gothenburg. When layers of clothing are rubbed against each other, electric charges can be built up. These were investigated by standardized rubbing of the fabric to be tested against a piece of cotton/polyester such as is used for working in hospitals (Hambraeus & Ransjö, 1977). The charge propensity of the fabric was considered high if it exceeded 50 kV/m, low if between 10–50 kV/m, and very low if less than 10 kV/m. Each value is a mean of six determinations. The resistivity of each fabric was also measured.

Water absorption

Determination of water absorption was performed according to SIS 25 12 28. The water uptake was measured as weight per cent during 30 min. Each value is a mean of two determinations.

Fabrics tested

The general properties of the fabrics tested are shown in Table 1, columns 2–4. The particle penetration (column 5) was measured with room air (Hambraeus & Ransjö, 1977). Green cotton is the textile used for common operating room gowns. Ventile fabrics L19–L34 are textiles used for a variety of purposes, including ultra-clean surgery (Charnley, 1972; Mitchell & Gamble, 1974). As the Ventile fabrics are waterproofed and the water repellency is said to be maintained for 33 washings (Brigden, 1964), two of the Ventile fabrics were retested after ten launderings with household detergent at 60 °C. Nomex[R] is a non-linting, fire-resistant polyamide yarn which has been used for clean room garments in various weaves (Shrank, 1973). Tyvek[R] is a non-woven polyethylene fabric used for disposable clothes (Seaman & Weimar, 1973). Mölnlycke Klinidrape[R] is a non-woven fabric consisting of rayon, used for disposable gowns with plastic-laminated front and sleeves (Hoborn, 1977).

RESULTS

The results of the rubbing tests are shown in Table 2.

Rubbing without barrier (Figs. 1 and 2).

That contact gave a high contamination of clothes was apparent from the pieces of cotton used as sources of bacteria for the new test instrument. In dry rubbing the average amount sampled was 15000 c.f.u./m^2 during the first 15 min sample, and in wet rubbing > 33000 c.f.u./m^2.

To see how far sampling diminished the numbers of bacteria recovered from the source material, one series with source fabric only was done with dry rubbing and

Table 2 *Results of rubbing tests with different fabrics*

Fabric	Electric charge propensity (kV/m)	Dry rubbing % penetration	Water absorption weight %	Wet rubbing % penetration
Green cotton	33	14	149	145
Ventile				
L19, washed twice	—	15	61·5	5
L24, unwashed	—	2	—	6
washed × 10	—	—	—	23
L32, unwashed	30	13	27	19
washed × 10	—	—	94	20
Nomex	< 1	30	160	77
Tyvek	165	14	267	101
Klinidrape	27	7	216	167
Klinkdrape + polyethylene laminate	37	< 1	—	< 1

one with wet. With dry rubbing the numbers of bacteria recovered sank during the first two 15 min periods to one third of that found on the first plate, and thereafter fell only slowly. With wet rubbing the numbers recovered fell throughout the whole series of ten 15 min periods to about one-fifth of the initial value.

Dry rubbing with barrier fabrics

As can be seen (Fig. 1) the penetration through all the fabrics tested remained fairly constant during the experiments. Nomex had a bacterial penetration rate of about 25 %. Most of the other materials: green cotton, Tyvek, Klinidrape and Ventiles L19 and L32 had a penetration rate of about 10 %. Ventile L24 seemed to give a somewhat lower bacterial penetration of 2 %.

Wet rubbing with barrier fabrics

In the wet rubbing, three groups of fabrics were seen (Fig. 2). The first group contained green cotton, Tyvek and Klinidrape, which all had around 100 % bacterial penetration (between 77 % and 167 %) after 30 min sampling and remained so. Tyvek and Nomex had a somewhat lower penetration during the first 15 min, but green cotton and Klinidrape reached their peak levels already on the first sampling plate.

In the second group of fabrics, Ventile L32 unwashed and L24 washed ten times were found to have a penetration of about 20 % after 30 min and to reach their peak levels of penetration, 40–50 %, after 45 min. The third group of fabrics was represented by Ventile L19, L24 unwashed and L34 unwashed, with a penetration of 1–6 % at 30 min, and by Klinidrape with plastic laminate where no penetration at all could be detected. The penetration through the Ventile fabrics did not reach a peak level during the experiment.

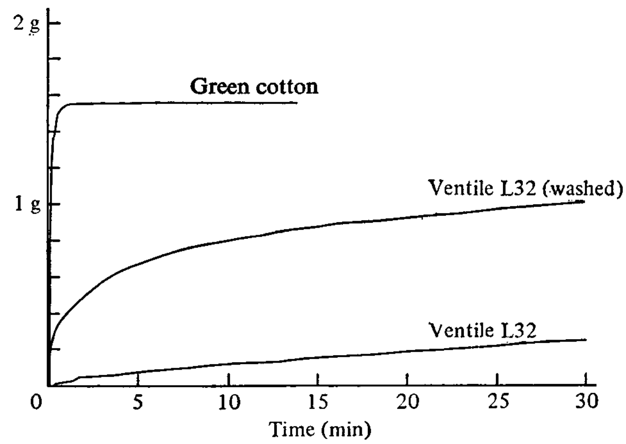

Fig. 3. Water absorption curves for green cotton, unwashed and washed Ventile L32 (sample diameter 9 cm).

Electric charge propensity

As the sampling filters became visibily charged electrostatically, the charge propensity of the fabrics was tested. Most fabrics had a low charge propensity of around 30 kV/m with a short, or very short, discharge time. Two exceptions were found: Nomex, which did not become measureably charged, and Tyvek, which was highly charged, mean 165 kV/m, and which retained this for at least ten min.

Water absorption

As the source cloth was visibly wetted through the fabrics tested at the end of wet rubbing experiments, the water absorption of the fabrics was measured (Fig. 3). A high water absorption of more than 150 % of the material weight was found for green cotton, Nomex, Tyvek and Klinidrape. The speed of absorption was greatest for green cotton, where the saturation level was reached in less than one minute. An intermediate water absorption of 60–100 % was found in the Ventiles L19, L34, and when washed L32, with a rapid absorption initially that slowed down after the first minute but did not reach saturation during 30 min. The unwashed Ventile L32, in contrast, had a water absorption of 27 %, and a very slow absorption speed. Water uptake curves for green cotton, unwashed and washed Ventile L32 are shown in Fig. 3.

DISCUSSION

Results obtained from different particle penetration tests, which may be used for the selection of fabrics for barrier garments are inconsistent (Lidwell & Mackintosh, 1978) and the results of such tests are not in agreement with the performance of the fabrics in clothes used in nursing (Ransjö, 1979). A new instrument was therefore designed for testing fabrics intended for barrier garments. By friction, bacteria from a source material were forced through a barrier material on to a dry or wet sampling surface.

In the investigation of test fabrics in the dry state, the bacterial penetration through most materials was around 10 %, irrespective of what the particle penetration tests had shown. These results are well in agreement with the findings in experimental nursing (Table 1) (Hambraeus & Ransjö, 1977). As electrostatic charges may influence the contamination of surfaces (Lidwell, 1967), the charge propensity of the materials was measured. Two fabrics differed from the others, one with a very high and one with a very low chargeability, but this was not correlated with other results with the fabrics.

The bacterial counts recovered from the source cloth were about three times higher when measured with wet than with dry rubbing, both with and without barrier materials. The reason for this is probably that each bacteria-carrying particle on the source cloth consists of a microcolony of some bacteria (Lidwell, Noble & Dolphin, 1959). A microcolony can be separated into smaller units, and the separation is more complete in a fluid suspension than on a dry durface (Holt, 1971). Wetting a microcolony on the source cloth would then give rise to more colony-forming units than dry rubbing. Penetration through wet fabrics differentiated between the materials more than did the dry fabrics. One group of fabrics rapidly let through about 100 % of the bacteria from the source cloth, and this group contained fabrics that were good air filters as well as poor ones. Another group of fabrics, containing the closely woven, waterproofed Ventile fabrics and a plastic-laminated non-woven fabric, had a much lower bacterial penetration which increased only very slowly during testing. The bacterial penetration through wet fabrics in wet sampling was closely correlated with the water absorption of the fabrics. Those with high wettability also let through more bacteria. The penetration through Ventile rose 3–4 times after several home washings, as did the water absorption. The fact that fabrics that are fairly good air filters let through a considerable amount of bacteria when wet probably accounts for the failure of some new barrier garments in clinical trials (Ransjö, 1979) (Table 1). Measurements with the new instrument might give guidelines for the development of better clothes for barrier nursing and surgery. The results of this investigation indicate that a plastic-laminated fabric or a freshly waterproofed closely woven cotton are among the most promising fabrics for protective clothing.

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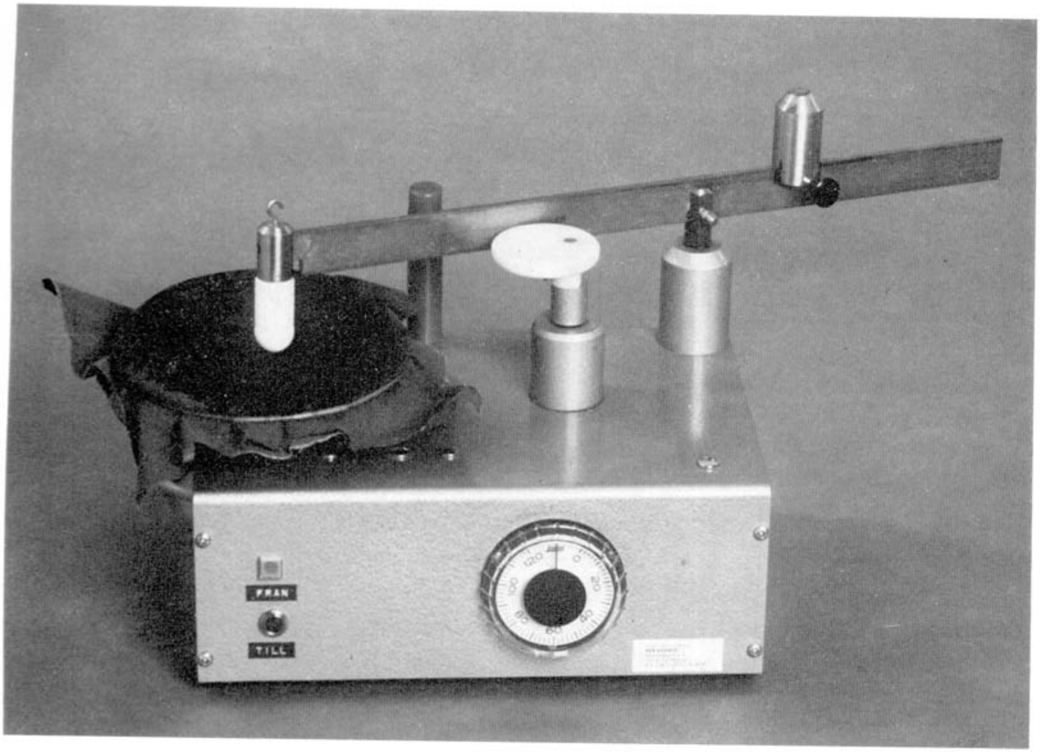
EXPLANATION OF PLATE

RULLA, the instrument, during wet rubbing.



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