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ANTIBIOTIC-RESISTANT STAPHYLOCOCCAL DISEASE: AN OBSTETRIC, SURGICAL, PAEDIATRIC AND HOSPITAL ADMINISTRATIVE PROBLEM

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Within recent years staphylococcal disease is being reported more and more frequently, and our American and British colleagues are worried by the high incidence of staphylococcal sepsis in hospitals.

The American Medical Association convened a conference of experts at Cleveland on 14 November 1957, and the essentials of the conference have now been published.[1,2] The experts remarked on the widespread dissemination throughout the hospitals of the United States and Canada of highly virulent, readily communicable, antibiotic-resistant strains of *Staphylococcus aureus* with a tendency to produce nasal carriers, skin lesions, wound sepsis, soft-tissue infections, and pneumonia. Neonatal infections and breast abscesses among nursing mothers were specially noted as troublesome to the sufferers and likely sources of spread of dangerous staphylococci to the general population.

The Lancet,[3] in May 1958, asked these pertinent questions: How many hospitals in Great Britain are confident about the efficacy and safety of their sterilizing and laundry procedure? How many provide clean air, or even abstain from doing operations and wound dressings in air that is richly charged with pyogenic bacteria? How many hospitals have effective procedures for checking whether members of staff with septic lesions on their persons are going about their duties and operating on, or otherwise attending to patients whose tissues may have a lowered capacity to resist infection? In how many hospitals are junior medical staff or even nursing staff left to prescribe whatever antibiotics they happen to think might be useful? *

In practice we regularly transgress in all these aspects of hospital routine. Laundries contaminate articles that were formerly free of pathogens. Hospital air is sucked from anywhere to anywhere else.

Fluffy woollen blankets provide warmth scarcely needed in centrally heated hospitals; they cannot be sterilized or even very often washed without ruining them, and they fill the air with bacteria-laden dust.

Staphylococcal disease is being more frequently reported in obstetric and paediatric wards,[6-12] causing infantile pyodermia, staphylococcal peritonitis in the newborn, umbilical infection, bullous impetigo and puerperal mastitis. Antibiotic-resistant staphylococcal outbreaks in medical and surgical wards are also being reported.[13]

* An Editorial[4] in the *South African Medical Journal* of 24 May 1958, based on an article by Laurie[5] in the same issue, also dealt with the dangers of hospital infection and problems it presented.

SOURCES AND MODES OF SPREAD OF STAPHYLOCOCCAL INFECTION

Because of the presence in Grey's Hospital of a number of cases of wound sepsis, an investigation was conducted, commencing in September 1957, to determine the incidence of staphylococcal infection in the medical, surgical and obstetric departments.

Technique

Staphylococci for investigation were isolated in the routine laboratory on blood-agar plates, and all coagulase-positive strains were kept for further investigation.

Blood-agar plates were used for isolating staphylococci from nasal swabs and the bedding, curtains and air of the wards and theatres. Samples from bedding were taken by the sweep technique of Blowers and Wallace.[14] All coagulase-positive strains isolated in this way were tested for sensitivity to penicillin, streptomycin, tetracyclines, chloramphenicol and erythomycin by the disc method. The concentrations of antibiotics used were: Penicillin and streptomycin 10 units per disc; chloromycetin 20 μg. per disc; aureomycin, terramycin and achromycin 25 μg. per disc; erythromycin 10 μg. per disc. The Oxford staphylococcus was used as a control, and a control sensitivity test was done throughout the investigation.

The air in the theatre suite and wards was sampled by a slit sampler,[15] the intake being about 2½ feet above floor level. No fans were used to drive the air from the patient to the sampler. The sampler plates were usually rotated at 1 revolution in approximately 2 minutes.

Tables I-IV give an idea of the high bacterial air count in the theatre suite and surgical wards. A strain of *Staph. aureus*, resistant to all antibiotics except chloromycetin and erythromycin was present in one of the male surgical wards.

TABLE I. AIR COUNT: THEATRE SUITE (Fig. 1), 28 SEPTEMBER 1957

Room	*Air count per cu. ft.*	*Notes*
1. Linen room	153	1 colony haemolytic streptococci
2. Theatre 2 (fan working)	286	2 colonies haemolytic streptococci
3. Sterilizing room (2)	154	No pathogens
4. Plaster room	98	No pathogens
5. Theatre 3	67	No pathogens
6. Sterilizing room (3/4)	74	No pathogens
7. Scrub-up room	62	No pathogens
8. Theatre 4	65	No pathogens
9. Theatre 4	53	No pathogens
10. Theatre 4	60	No pathogens

TABLE II. AIR COUNT: OBSTETRIC AND PAEDIATRIC WARDS, 3 OCTOBER 1957

Ward	*Air count per cu. ft.*	*Notes*
J. Ward (main ward)	143	*B. proteus* present
J. Ward (room no. 8) (both paediatric)	76	No haemolytic streptococci or staphylococci
Labour room (European maternity ward)	15	No haemolytic streptococci or staphylococci

TABLE III. AIR COUNT: SURGICAL WARDS, 3 OCTOBER 1957

Ward	*Air count per cu. ft.*	*Notes*
D. Ward (A side)	178	2 colonies of haemolytic streptococci per 4 cu. ft.
D. Ward (B side)	156	3 colonies of haemolytic streptococci per 4 cu. ft.
B. Ward ('dirty' surgical)	196	2 colonies of haemolytic streptococci per cu. ft.
B. Ward ('clean' surgical)	115	No haemolytic streptococci

TABLE IV. SENSITIVITY TO ANTIBIOTICS OF STRAINS ISOLATED FROM AIR SAMPLES IN SURGICAL WARDS, 28 OCTOBER 1957

Antibiotic	*Haemolytic Streptococcus D Ward*	*Haemolytic Streptococcus B Ward*	*Staphylococcus aureus coagulase-positive; B Ward*
Penicillin	Sensitive	Sensitive	Resistant
Aureomycin	Resistant	Resistant	Resistant
Chloromycetin	Sensitive	Sensitive	Sensitive
Streptomycin	Sensitive	Sensitive	Resistant
Terramycin	Resistant	Resistant	Resistant
Erythromycin	Sensitive	Sensitive	Sensitive
Achromycin	Resistant	Resistant	—

THEATRE SUITE

The conditions in the theatres were particularly bad, and it was decided to attempt to improve conditions in the theatre suite as a matter of urgency. In the plan of the theatre suite (Fig. 1) it can be seen that a passage bisects the suite, this passage being the main highway between the hospital entrance and the surgical wards. The general condition of the theatre suite was bad. The floors were unsound; the passages were covered with 'battleship' linoleum, which allowed dust and dirt to accumulate underneath and along the edges of the linoleum. Some of the ceilings were old, the paint was chipping away, and dust in the ceiling was seeping through into the theatres. The air conditioning was unsatisfactory and required complete revision and overhaul to ensure balanced conditions.

Immediate steps were taken to improve matters by replacing the doors in the main passage way (A and B) and closing this passage to all traffic. An antiseptic (germotol) was used to spray the theatres, and air counts on 15 October 1957 (Table V) showed that the count had been reduced tenfold.

TABLE V. AIR COUNT: THEATRE SUITE, 15 AND 16 OCTOBER 1957

Place of Sampling	*Air count per cu. ft.*
Theatre 4, near door to scrub-up	8·3
Theatre 4, near door to sterlizing room	10
Theatre 4, near main doors	18
Theatre 4, by windows	9·2
Theatre 4, by operating table	10·2
Theatre 4, near wall	5·5
Average count for theatre 4	10·2
Corridor outside Theatre 4	31
Corridor near plaster room	39
Tea room (10.30 a.m., just after use)	35
Theatre 3 immediately before 10 a.m. operation	26

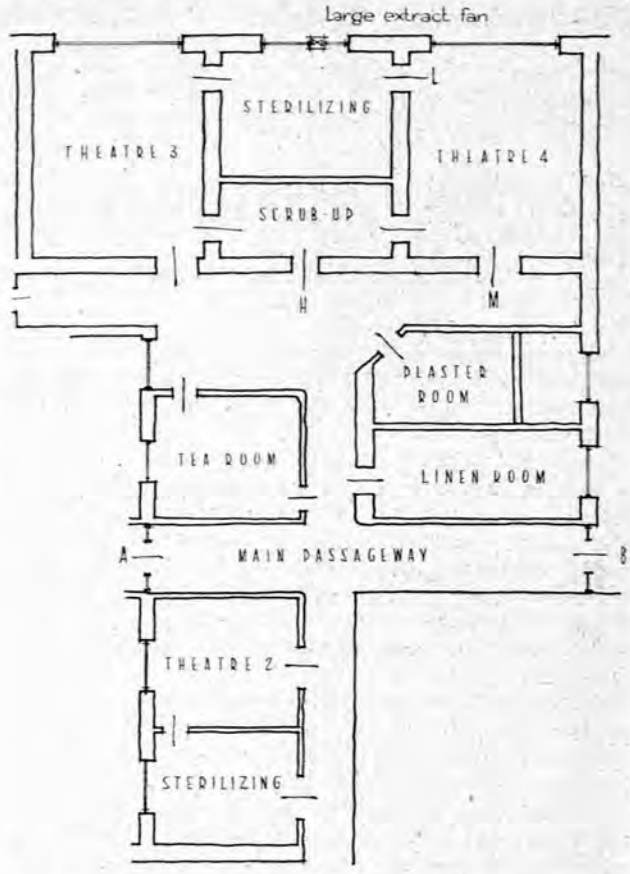

Fig. 1. Theatre suite.

Comments. Theatre 4 was sampled under ideal conditions. The theatre was sealed off and the technician wore gown, cap and mask. The theatre had been sprayed about 30 minutes before the first sample was taken. The negative pressure in the theatre (see below) was responsible for a great deal of the pollution. This theatre is used for burns and major surgery, and therefore falls far short of the standard (a maximum of 2 organisms per cubic foot).

HOSPITAL BLANKETS

In September 1958 sweep sampling[14] was performed on hospital blankets (Table VI), which showed a very high reservoir of infection in all the wards. Twenty strokes over the surface of the blanket produced a heavily contaminated plate. Ten strokes were tried, and on an average

TABLE VI. RESULTS OF STROKE SAMPLING OF BLANKETS

Blanket	*Viable organisms per plate*
1. On trolley in main operating theatre	470 (approx.)
2. Covering patient waiting to enter operating theatre	180
3. Stretcher blanket of theatre 2	900 (approx.)
4. On bed in B ward	250
5. In store of A ward	250
6. Outside delivery room of M2 ward	560 (approx.)

produced plates with colonies sufficiently differentiated to make counting and investigation of the organisms a possibility. Five circular motions with a radius of about 8 inches produced a more evenly seeded plate, and this method was used to obtain the samples referred to in Table VI.

Pathogenicity of Organisms Isolated from Blankets

1. Several colonies from each plate were investigated and antibiotic sensitivity tests were carried out on pathogenic organisms. The majority of the organisms belonged to the group associated with normal air pollution, viz. *Staph. saprophyticus*, sarcinae, coliforms, *Neisseria catarrhalis*, etc., but the following pathogenic organisms were isolated:

(*a*) A growth of *Staph. pyogenes* was isolated from sample 1 (Table VI) and was found to be sensitive to all the antibiotics listed in Table IV.

(*b*) A growth of *Staph. pyogenes* was isolated from sample 5 and was found to be resistant to aureomycin, terramycin, and achromycin, moderately sensitive to penicillin, and sensitive to chloromycetin, streptomycin and erythromycin.

(*c*) A growth of *B. proteus* was isolated from a bed in B ward (sample 4) and was found to be resistant to all the antibiotics in the list.

2. Anaerobic samples were taken from blankets in the operating theatre. No anaerobic organisms were isolated from them.

3. Twelve samples on agar containing crystal violet (for haemolytic streptococci) were taken in F ward. One colony of B haemolytic streptococci were isolated and several of A haemolytic streptococci.

The ease with which *Staph. pyogenes* and other pathogens could be obtained from hospital blankets indicated the danger of blankets as a source of infection in the wards, labour rooms, and theatre suites.

Sterilization of Blankets

Examinations were conducted to determine whether sunlight was a good bacteriocidal agent. Sweep plates before and after 8 hours' exposure to sunlight showed no reduction in the bacterial count. Formaldehyde vapour was also tried. Blankets suspended in formaldehyde vapour* for 2 hours showed very little reduction in the bacterial count, but after exposure in the vapour for about 24 hours there was a marked reduction in the bacterial count.

It was therefore decided to change the woollen blankets in the surgical and orthopaedic wards every 2 weeks and formalize them before returning them to the ward. It was also decided to launder the blankets more often, and in laundering to wash them in cirrasol.[14]

In addition to these precautions it was decided to remove ward blankets from patients' trolleys before entering the theatre, and to replace them with sterile cotton blankets (sterilized with pressure steam). Because of the danger that woollen garments may harbour pathogenic organisms, medical practitioners were requested to change from their day clothes into a cotton singlet and trousers and to wear a clean cap, mask and boots, before entering the operating theatres.

* In a closed room 13 × 14 × 10 ft. (=1,820 cu. ft.) 3 oz. of potassium permanganate is added to 8 oz. of formalin (40%) in a large vessel.

Theatre Suite

It was decided to repeat the slit sampling of the air in theatre 4 now that only sterile cotton blankets were allowed into the theatre. Four counts made in October 1958 gave 3, 4, 6 and 16 organisms per cu. ft. respectively.

As sterilizing in the theatre was done by the boiling-water method, a large extraction fan was used to remove the air from the sterilizing room (Fig. 1). This resulted in a strong flow of air into theatre 4 by door M and out by door L. It was decided to close the louvre in door L, and make new openings which diverted the air flow from the passage through the scrub-up room and sterilizing room. Three air counts in theatre 4 made after this alteration gave 1·5, 2·0 and 3·5 organisms per cu. ft. respectively —almost normal.

DEATHS OF PREMATURE INFANTS

On about 1 October 1958, 5 premature infants, nursed in incubators, succumbed in the non-European maternity ward. Of these deaths 2 were due to prematurity, but 3 of the infants died on or about the 10th day with a blood-stained discharge from vagina, rectum and mouth. Air samples were taken from the incubators concerned, and from stools of the infants that had died, and sweep samples from clean napkins in the maternity ward. Staphylococci, coagulase positive, sensitive only to erythromycin, were isolated from the clean napkins, the interior of the incubators, and a stool from one of the infants that had died.

Viral studies on tissue sent to the S.A. Institute for Medical Research from one of the infants that had succumbed proved negative for the Coxsackie virus.

Phage-typing of one of the staphylococcus cultures from a premature infant that died gave a pattern of phage-type 80. A midwife who attended these premature infants developed an acute staphylococcal infection of the right hand, necessitating her confinement to the ward. Typing of one of the cultures from her hand gave phage-type 80. It is evident, therefore, that these infants died from an acute staphylococcal phage-type-80 infection. This organism was resistant to all the common antibiotics except erythromycin.

The phage-type-80 staphylococcus has been identified in Europe since 1955, and has been observed in various parts of the world, including the USA. It has been the cause of all serious infections in wards and outbreaks in hospitals.

In view of the presence of this virulent strain of staphylococcus, the following measures were taken:

1. The nursery and premature nursery were closed to further admissions.

2. Newborn infants born after the day the nurseries were closed were transferred to a vacant floor above, with their mothers.

3. As soon as this had been effected (about 10 days), brick partitions in the general maternity ward were removed. The ward was repainted and redecorated, and the number of beds reduced from 20 to 14.

4. The nurseries were fumigated with formalin, and the incubators were well scrubbed out and washed with germatol. Repeated cultures from the incubators proved that they were extremely difficult to sterilize, and further examination showed that the best way to sterilize them was to leave them in formalin vapour for 24 hours.

5. Only autoclaved linen was used in the incubators.

6. Nursing staff were instructed to wash their hands with hexachlorophene before each baby bath.

7. Only sterile cotton blankets were used in the labour rooms.

8. 'Savlon' was used to wet-sweep the floors and walls of the labour room.

9. Nose, throat and vaginal swabs were taken of all new patients for a month, to decide if the mothers were carriers of the staphylococcus. This investigation showed that they were not, and that the staphylococcus was endemic in the ward.

ANALYSIS OF HOSPITAL STAPHYLOCOCCAL INFECTION

An analysis of the occurrence of hospital staphylococcal infection over the 7 months period from 15 June 1958 into January 1959 was made at the end of December 1958. The total number of cases during this period was about 54, as follows:

June	3	October	7
July	2	November	13
August	2	December	19
September	4	January	4

The staphylococcus isolated from various departments of the hospital and from patients suffering from staphylococcal infections had a definite pattern of sensitivity; it was resistant to penicillin, aureomycin, streptomycin, terramycin, and achromycin, and sensitive to chloromycetin and erythromycin.

Because of the increasing number of staphylococcal infections, it was decided to isolate patients and nursing staff suffering from staphylococcal disease showing this pattern of resistance to antibiotics. A ward, M.1, was accordingly opened in November 1958 where these cases were isolated and treated.

RESULTS OF ROUTINE STERILIZING OF BLANKETS AND WET DUSTING WITH 'SAVLON'

Table VII shows the results of slit sampling of the air in the surgical wards after routine sterilizing of blankets and wet dusting with 'savlon' had been instituted, as compared with the results obtained on 3 October 1957 (Table III).

TABLE VII. AIR COUNT : SURGICAL WARDS

Ward	*Date of silt Sampling*	*Organisms per cu. ft.*
D Ward (A side)	3 October 1957	178
	9 January 1959	9
B Ward ('dirty' side) ..	3 October 1957	196
	31 December 1958	14*
B. Ward ('clean' side) ..	3 October 1957	115
	31 December 1958	12

* Four samples were taken at different times in the day; 40 cu. ft. of air at each sample yielded an average count of 14 viable organisms per cu. ft. One colony of haemolytic streptococcus was isolated.

Further Observations in B Ward, 17 December 1958

Brooms. Springing the broom hairs on to the plate yielded a heavy growth of viable organisms. No pathogens were isolated.

Curtains. Ten sweeps yielded a growth of 6 viable organisms per plate. No pathogens were isolated.

Blankets. Ten sweeps per blanket yielded an average of 15 viable organisms per plate. No pathogens were isolated.

DISCUSSION

This investigation into the cause of wound sepsis brought to light the alarming fact that the air in the theatre suite was highly contaminated by airborne organisms, some of which were pathogenic. This high airborne count was probably the direct cause of wound sepsis. For many years it has been generally believed that the chief cause of fresh infection of wounds in operating theatres is direct contact with some infected solid or liquid matter. While this was certainly true when somewhat imperfect aseptic techniques were employed, the continual improvement which is being made in the cleanliness of instruments and other objects in contact with wounds must in time reach a point at which the number of fresh infections from dirty air becomes an appreciable fraction of all such infections. When that point is reached, attention to the cleanliness of theatre air becomes important.

The air-counts in the surgical wards were also extremely high, and a staphylococcus was present which was endemic in all departments, showing a characteristic pattern of resistance to the antibiotics in general use.

Sweep plates of blankets, ward curtains and linen revealed a reservoir of infection which proved difficult to eradicate. The endemic strain of staphylococcus was present in the incubators, linen and blankets of the midwifery wards, where it led to the death of 3 premature infants before the infection was traced to its source and dealt with. These fatalities from staphylococcal disease in infants nursed in incubators indicate the danger from incubators which are not sterile. Incubators afford favourable conditions for the growth of pathogenic organisms, and unless scrupulous care is taken to sterilize them before use, and to use only autoclaved linen in them, there is a danger of infection occurring in the infants.

Preventive Measures

Theatre suite. By closing the theatre suite to unnecessary traffic, altering the flow of air through the theatres, and not allowing contaminated woollen material such as blankets and doctor's clothes into the theatre, the air count was reduced to normal.

Surgical wards. By fumigating blankets by suspending them in formaldehyde gas for 24 hours, and the wet dusting of wards, the air count in the wards was reduced to normal.

Maternity section. Staphylococcal disease in premature infants was aborted by fumigating the incubators by exposing them to formaldehyde gas for 24 hours, autoclaving the linen used in the incubators, and insisting on a hand-washing routine with hexachlorophene soap.

Other measures taken were to use sterile cotton blankets in the labour rooms, and to wet-dust with dusters wrung out in 'savlon'.

SUMMARY

Staphylococcal disease in Grey's Hospital was studied for 15 months.

Air counts in the theatre suits and surgical wards revealed high bacterial counts with pathogenic organisms, resistant to many antibiotics.

The air count in the theatre suite was reduced to normal by:

(1) altering the air flow through the theatre;

(2) allowing only sterilized cotton blankets to be introduced into the theatre; and

(3) insisting on surgeons changing into cotton singlet and trousers and wearing caps, masks, boots and gowns.

Air counts in the wards were reduced to normal by sterilizing blankets and wet-dusting.

An outbreak of staphylococcal disease, phage-type 80, in premature infants nursed in incubators was aborted by using only autoclaved linen in the incubators and sterilizing the incubators.

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REFERENCES

1. Conference on Staphylococcic Infections (1958): J. Amer. Med. Assoc **166**, 1177.
2. Ravenholt, R. T. (1958): Amer. J. Publ. Hlth, **48**, 277.
3. Editorial (1958): Lancet, **1**, 1055.
4. Editorial (1958): S. Afr. Med. J., **32**, 536.
5. Laurie, W. (1958): *Ibid.*, **32**, 537.
6. Ravenholt, R. T. (1956): Amer. J. Publ. Hlth., **46**, 1287.
7. Wysham, D. N. *et al.* (1957): New Engl. J. Med., **257**, 295 and 304.
8. Colbeck, J. C. (1949): Canad. Med. Assoc. J., **61**, 551.
9. Beaven, D. W. (1958): Lancet, **1**, 869.
10. Tolentino, P. (1952): Arch. Dis. Childh., **27**, 262.
11. Duncan, J. T. and Walker, J. (1942): J. Hyg., **42**, 474.
12. Gillespie, W. A., Pope, R. C. and Simpson, K. (1957): Brit. Med. J., **1**, 1044.
13. Barber, M. and Dutton, A. A. C. (1958): Lancet, **2**, 64.
14. Blowers, R. and Wallace, K. R. (1955): *Ibid.*, **1**, 1250.
15. Medical Research Council (1948): *Studies in Air Hygiene.* Spec. Rep. Ser. Med. Res. Coun. (Lond.).