lungs and dissecting away the pericardium, leaving the aorta and pulmonary trunk undisturbed except for cutting them across just above the valves. When this has been done the ductus can be seen to cross the descending aorta from right to left at a very acute angle and enter it, as described, on its antero-lateral aspect. When the vessels are removed from the body their elasticity abolishes this relationship.

Summary

Post-mortem observations show that the ductus arteriosus may be contracted or uncontracted. In most infants that have lived independently it is contracted, while in most stillborn infants it is uncontracted. These observations are taken to support the idea that active contraction of the ductus is associated with the onset of respiration.

Most of the stillborn infants were mature, and most of the neonatal deaths were of premature infants. In both stillbirth and neonatal death there were more examples of uncontracted ductus among mature infants than among premature infants. The questions inherent in these findings require further study.

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REFERENCES

- Born, G. V. R., Dawes, G. S., Mott, J. C., and Rennick, B. R. (1955). *J. Physiol. (Lond.)*, 129, 28P.
 Danesino, V. L., Reynolds, S. R. M., and Rehman, I. H. (1955). *Anat. Rec.*, 121, 801.
 Everett, N. B., and Johnson, R. J. (1951). *Ibid.*, 110, 103.
 Jager, B. V., and Wollenman, O. J. (1942). *Amer. J. Path.*, 18, 595.
 Kennedy, J. A., and Clark, S. L. (1941). *Anat. Rec.*, 79, 349.
 Lind, J., and Wegelius, C. (1954). *Cold Spr. Harb. Symp. quant. Biol.*, 19, 109.
 Mitchell, Sheila C. (1957). *J. Pediatr.*, 51, 12.
 Noback, G. J., and Rehman, I. (1941). *Anat. Rec.*, 81, 505.

AN OUTBREAK OF POST-OPERATIVE SEPSIS

BY

E. J. K. PENIKETT, M.B., B.S.

AND

R. KNOX, M.D., F.R.C.P.

Department of Bacteriology, Guy's Hospital Medical School, London

AND

J. LIDDELL, M.B., B.Chir.

Department of Clinical Pathology, Guy's Hospital, London

Outbreaks of post-operative sepsis are not uncommon, and many have been reported (Devenish and Miles, 1939; Sevvitt, 1949; Blowers, Mason, Wallace, and Walton, 1955; Shooter, Taylor, Ellis, and Ross, 1956; Shooter, Griffiths, Cook, and Williams, 1957). A recent outbreak at Guy's Hospital followed a common pattern, but the evidence which suggested the probable route of cross-infection was unusually clear-cut. The details of the investigation and findings are presented in the hope that they may suggest means of preventing further outbreaks of this kind.

In February, 1957, two surgeons, Mr. A and Mr. B, noted an increase in the incidence of post-operative sepsis among their patients. Their impression was that, although they and their registrars operated elsewhere, sepsis occurred only among those patients whose operations were performed in one particular theatre at Guy's Hospital (theatre 3). This theatre was also used

by other surgeons, but they had not noticed any trouble. It was thought that ward cross-infection was unlikely, because the wards were shared with other surgeons whose patients were not infected. In view of this information we decided to concentrate attention on one particular operating theatre, and accordingly samples were collected from a variety of sources to see whether a possible pathogen could be identified.

Chronological Account of Main Events

On Thursday, February 14, settle plates were exposed, samples of air were taken, and furniture and fittings were swabbed during Mr. A's operating session. Pieces of suture material were taken for culture from the sterile suture trolley.

By the next day it was apparent that one piece of "terylene" suture material was infected with a Gram-positive coccus and that staphylococci had been cultured from the samples of air and from swabs of fixtures. The organism infecting the terylene suture proved to be *Staphylococcus pyogenes*. It was known that Patient D had been ligated and his wound sutured with this material. It was at once thought that the terylene sutures had escaped sterilization. Samples of suture were taken from theatre stocks and cultured. Further samples were taken after having been autoclaved in the customary manner. Neither the samples taken before autoclaving nor those taken after autoclaving were found to be infected with *Staph. pyogenes*. However, the sterilization process was not perfect, as the cultures of three of the samples of autoclaved suture grew a saprophytic actinomyces after prolonged incubation.

Nose and throat swabs were taken from all nursing staff working in theatres, the theatre orderlies, Mr. A, his registrar and house-surgeon, and the medical students on Mr. A's firm. Staphylococci were found in the nose of some of these and in the throat of one nurse. Patient D had now developed signs of wound sepsis and soon discharged pus from which *Staph. pyogenes* was cultured.

This was the state of affairs by Monday, February 18, when Mr. A again operated. Further samples of terylene suture material were taken from the suture trolley, but in view of what had happened previously none was used on the patient (Patient J).

Several of the staff with staphylococci in their noses could have infected patients previously under Mr. A's care, especially the registrar and the scrub nurse (Nurse X). The registrar knew himself to be a nasal carrier of staphylococci, but had not had any post-operative sepsis among patients upon whom he had operated in theatres other than theatre 3. Nurse X had started work in the theatre the previous December and the outbreak started in January. She always scrubbed for Mr. A. and Mr. B. In view of this strong circumstantial evidence she was withdrawn from the operating theatres. As an additional precaution all the nasal carriers among the nursing staff were temporarily suspended, as were the medical students until the results of phage-typing were known.

Patient J developed post-operative sepsis and discharged pus. The terylene suture material collected on the occasion of his operation but not used in him was found to contain staphylococci.

The staphylococci cultured from Patients D and J, Nurse X, and the suture material were all of the same phage type, which was different from the phage type of the rest. A staphylococcus cultured from a settle-plate placed near the scrub nurse on February 14 also proved to be of the same phage type. These strains were penicillin-resistant but sensitive to streptomycin, chloramphenicol, erythromycin, tetracycline, and novobiocin. No further case of sepsis occurred after Nurse X was withdrawn.

Nurse X was not allowed to return to work in the theatres and the outbreak ceased.

The investigation tended to centre in Mr. A's firm, but as further information was collected it was found that two

patients (L and T) operated on by Mr. B with Nurse X's assistance had discharged pus which yielded *Staph. pyogenes* of the same "epidemic type" phage pattern.

Results in Greater Detail

The foregoing gives an overall picture of the outbreak. A more detailed account of the results is given below.

Nose and Throat Swabs.—Nose and throat swabs were taken from 23 theatre nurses and orderlies. Five were heavy nasal carriers of *Staph. pyogenes*, and one nurse's throat was heavily infected. Eleven medical students were swabbed. Three were nasal carriers of *Staph. pyogenes*. Mr. A's registrar was a nasal carrier, but Mr. A. and his house-surgeon were not. The nose swabs were repeated 14 days later with the same result.

Swabs of Fixtures, Air Sampling, etc. (February 14).—**Air (settle plates):** One plate was exposed on the window-ledge by the needle-tray, another on a stool near the door to the anaesthetic room, and one more on top of the sucker and diathermy machine. The results are shown in Table I. **Air**

TABLE I

Position of Settle-plate (Exposed Area, 12.6 sq. in.; 81 sq. cm.)	Settle Rate Orgs./hr.	<i>Staph. pyogenes</i> as a Proportion of Total Orgs.
Window-ledge	152	1/152
Sucker	169	None
Stool	112	2/112

(slit sampler): Samples of 5 cu. ft. (0.14 cubic metre) of air were taken at the beginning and near the end of the first operation, a laparotomy. The results are shown in Table II. **Furniture and Fixtures:** Swabs were taken as shown in Table III.

TABLE II

	Organisms		<i>Staph. pyogenes</i> as a Proportion of Total Orgs.
	Per cu. ft.	Per cu. metre	
Beginning of operation ..	30	1,766	8/247
Near end	25	883	8/123

TABLE III

Site	Culture	Pathogens Isolated
Floor A	Heavy mixed growth	<i>Staph. pyogenes</i>
" B	"	"
Portable lamp	Light	"
Anaesthetic machine top ..	Heavy	"
Window-ledge	Moderate	"
Ledge to prep. room hatch ..	"	"
Dressing drum trolley ..	Heavy	"

Suture Material (February 14).—Samples of nylon, catgut, and terylene suture material were collected from the suture trolley just before the start of the operation. Their immediate history was as follows. Mr. A's instruments and the terylene had been autoclaved together in one pack. The scrub nurse (Nurse X) removed the terylene from the pack and laid it on the suture trolley. She loosened the hanks and cut lengths ready for ligatures or loading-needles. An

assistant nurse dropped several sealed ampoules of catgut into a bowl of sterile saline. One or two ampoules were broken by Nurse X and the contents shaken into the bowl. The assistant nurse removed a bunch of nylon sutures from a jar of biniodide of mercury and put them on the suture trolley. At this stage samples were requested. Nurse X, using forceps, lifted a piece of each type of suture and dropped them into separate sterile bottles.

The result of culturing the sutures was: nylon, no growth; catgut, no growth; terylene, *Staph. pyogenes*. Just before the operation on February 18, two samples of terylene were taken from the trolley immediately after Nurse X had unravelled and cut the hank. Both specimens proved, on culture, to be contaminated with *Staph. pyogenes*.

Incidence of Sepsis.—The following information was obtained from examining the records of Mr. A's patients: **Operations performed by Mr. A in theatre 3** from January 7 to February 28: 21 cases, 7 infected—4 with *Staph. pyogenes*, 2 with *E. coli*, 1 unknown. **Operations performed by Mr. A's Registrar in theatre 3:** 25 cases, 6 infected—2 with *Staph. pyogenes*, 4 unknown. Total: 46 cases, 13 infected—6 with *Staph. pyogenes*, 2 with *E. coli*, 5 unknown. 15 "take-in" cases were operated on by the firm, but not in theatre 3, with no infections.

Infection of Patients

Specimens from only five patients became available during the investigation. *Staph. pyogenes* of one type or another was isolated from all of these. All but one (Patient B) were Mr. A's patients.

Two of Mr. B's patients—Mr. L and Mr. T—subsequently discharged pus which contained *Staph. pyogenes* of the "epidemic type." Fresh specimens were obtained from patients D and J (group A) as soon as sepsis arose. It is worth noting that the strain of staphylococcus from the second specimen from Patient J (group D) was not of the "epidemic type." Patient B (group C) was an old-standing case and the original strain of staphylococcus may have been supplanted.

Patients K and S had had sepsis for three to four weeks before a specimen was sent for phage-typing. We have no means of knowing whether these patients were originally infected by the "epidemic type," but they could have been.

Patient S was the only one of these five operated on by Mr. A's registrar. The rest, except Patient B, were operated on by Mr. A. Patient B as stated above, was operated on by Mr. B.

Phage-typing

The phage patterns of the various staphylococci found have been arranged in groups—A, B, C, and D—according to advice from the Staphylococcal Reference Laboratory.

The arrangement suggests that there may be two epidemic types—that is, (1) groups A+B and (2) group C. However, the difference between group A and group C was the fact that the reaction with the phages was so much stronger with the latter. This would not suffice to distinguish two strains, but it was sufficient to distinguish the two groups when so many representatives of each were available.

TABLE IV.—Phage Patterns

Group A: "Epidemic Type" Strains				Group B: Impossible to say these strains are different from those in Group A			
Date, 1957	Source	Phage Pattern		Date, 1957	Source	Phage Pattern	
		Diluted	1,000 × R.T.D.			Diluted	1,000 × R.T.D.
21/2	Nurse X		52A/79 w	20/2	Nurse C		7+ (52A/79 w)
7/3	"		"	26/2	Student T		52A vw
24/2	Patient D		"	7/3	" W		"
24/2	" J		"	26/2	"		"
14/2	Terylene suture material ..		"	7/3	"		"
18/2	"		"	3/3	Nurse B		79
14/2	From settle-plate on window-ledge	52A vw	52A/79+ w	6/3	" M	79 w	
18/2	Terylene suture material ..		"	7/3	Student R	79 vw	
3/3	Patient L		52A/79 w				
3/3	" T		"				

+ = Additional minor reactions present. w = Weak reaction. — = No reaction obtained.

Group A (Table IV).—A connexion between the sources is easy to suggest—that is, Nurse X contaminated the suture material, perhaps by her gloves, and so the patients.

Group B (Table IV).—The only epidemiological evidence, apart from phage-typing, to suggest a relationship between group B and group A is that Nurse C worked with Nurse X to some extent, in that she was the preparation-room nurse. However, students T and W had no close connexion with Patients J and D, and they were not present during the operation on J.

Group C (Table V).—At first sight group C would seem to show another epidemic type. However, Nurse H did not work in theatre 3 nor did she have any contact with Patient

TABLE V.—Phage Pattern, Group C (? Another Epidemic Type)

Date, 1957	Source	Phage Pattern	
		Diluted	1,000 × R.T.D.
21/2	Nurse H	52A/79 +	
3/3	" "	"	
25/2	Patient B	"	52/52A/79/80
25/2	Mr. A's registrar ..	"	
1/3	" "	"	52/52A/79/80
26/3	Student L "	"	52A/79/80

See footnotes to Table IV.

B, who was operated on in theatre 5. Student L had no close contact with Patient B, nor did Mr. A's registrar.

Patient B was operated on by Mr. B 20 days before the swab was taken, and discharged pus on and off over that period. There is therefore no evidence that he was originally infected with the present type. Even without the evidence from the suture material, there are still good reasons for regarding group A as representing the epidemic type. This does not apply to group C, where there is no obvious connexion between the different strains. It may be that this type is a common ward strain.

The staphylococci from samples of air and dust are classified as miscellaneous (group D, see Table VI), with the single exception of the strain isolated from one settle plate (group A).

TABLE VI.—Phage Pattern, Group D Miscellaneous Strains Not Related to Groups A, B, or C

Date, 1957	Source	Phage Pattern	
		Diluted	1,000 × R.T.D.
21/2	Nurse C		52A vw
6/3	" P	77 w	
6/3	" D	"	
21/2	Orderly G	71 +	
6/3	"	71 +	
24/2	Patient S'		77 vw
28/2	" K	55/71 +	
7/3	" J	80	
14/2	Settle-plate stool ..	53/54/77 +	
4/3	Dust	53 54/77 +	
		7/53 77 +	
		75 77	
		7/53/77 + w	
		7/53 77 + w	
4/3	Air samples ..	38 55	
		7/53/75 77 + w	
		7/53/75/77 + w	

See footnotes to Table IV.

Discussion

In the outbreak here described nearly all the cases of sepsis followed operations in one theatre at which a particular nurse prepared the sutures. This circumstantial evidence was strengthened by finding that this nurse was carrying in her nose staphylococci of the same phage type as those isolated from suture material which she handled and from the wounds of patients at whose operations she had assisted. After the removal of this nurse from the theatre no fresh cases occurred. Either the circumstantial or the bacteriological evidence alone could have been misleading. For example, other bacteriological investigations showed that a surgical registrar was a nasal carrier of staphylococci of different type but of the same type as those isolated

post-operatively from the wound of one patient. Yet this registrar continued to operate though carrying the staphylococci in his nose, and no fresh cases occurred. On the other hand, the strain from the nurse could have appeared to be more dangerous than that of the registrar simply because the nurse had greater opportunities for infecting the patient.

It could be argued that there was no logic in excluding the nurse from the theatre and not excluding the registrar. Yet the combined circumstantial and bacteriological evidence showed that this decision was in fact justified. Whatever the reason may have been, the staphylococci carried by the nurse were more dangerous than those carried by the registrar.

In dealing with staphylococcal infections the ideal, of course, is not only to control outbreaks which have actually developed but to prevent them from developing at all. Once an outbreak has started, prompt combined action by all concerned may quickly bring it under control. But evidence as clear-cut as we had in the outbreak here described is not often obtained, and the control of an established outbreak may be a lengthy process. The crucial problem is how to recognize which staphylococci are dangerous. Unfortunately there are no reliable laboratory tests for this purpose. To regard all carriers of *Staph. pyogenes* (coagulase-positive staphylococci) as dangerous and exclude them from the theatres might mean closing theatres down for long stretches of time while a staff of staphylococcus-free surgeons and nurses was built up; and even if that were achieved there is always the risk of someone becoming a carrier of dangerous staphylococci and infecting both staff and patients.

But this does not mean that bacteriological investigations are useless. On a long-term basis we cannot deal intelligently with staphylococcal or any other infections unless we know the reservoirs of the infecting organism and the routes by which it spreads. There is much to be said for trying to establish records of carriers of *Staph. pyogenes* and the incidence of post-operative infections. If these records were regularly examined it might be possible to recognize an impending outbreak, and the search for carriers would be easier. Periodic examination of the air and dust in the wards and theatres would in the same way make it easy to recognize departure from the usual. Furthermore, these records would be of value to those interested in the epidemiology of hospital infections.

If such records had been kept prior to the outbreak described it is almost certain that it would have been recognized several weeks earlier and the investigation could have been carried out more efficiently and with less inconvenience to patients and staff.

Summary

The investigation of an outbreak of staphylococcal post-operative sepsis provided unusually clear-cut evidence of the probable chain of events leading to the infection of patients. It is thought that a scrub nurse was responsible for infecting materials and instruments used in the patients during operations. No further patients were infected when this nurse was removed from theatre duties.

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REFERENCES

- Blowers, R., Mason, G. A., Wallace, K. R., and Walton, M. (1955). *Lancet*, 2, 786.
 Devenish, E. A., and Miles, A. A. (1939). *Ibid.*, 1, 1088.
 Sevi, S. (1949). *Ibid.*, 2, 1075.
 Shooter, R. A., Griffiths, J. D., Cook, J., and Williams, R. E. O. (1957). *Brit. med. J.*, 1, 433.
 — Taylor, G. W., Ellis, G., and Ross, J. Paterson (1956). Post-operative wound infection. *Surg. Gynec. Obstet.*, 103, 257.