Post-operative Wound Sepsis

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INTRODUCTION

Before the time of Lister the record of hospital infection and particularly that of post operative sepsis, makes grim reading. During 1872 a young surgeon named Beck (1924. R.J. Godlee, Lord Lister.) made a study of the incidence of "hospital diseases" in University College Hospital, London, in an attempt to discover how far, if at all, these diseases were infectious, whether they were influenced by climatic conditions and whether they attacked particular wards or beds. In the surgical wards, containing in all 86 beds, 7 cases of pyaemia and 29 of erysipelas originated and several of these were fatal. Two years later Erichsen (1874) published a more detailed account. In the same hospital the total number of amputations performed in his wards was 307 and of these 79 died, a mortality of nearly 25%. This, however, he goes on to describe as reasonably satisfactory, the figure comparing well with 43% at the Edinburgh Infirmary and 39% at the Glasgow Infirmary. He quotes American figures as being good, at the Pennsylvania hospital - from 1831 to 1860 - the average mortality is low, only 24.3%, whilst at the Massachusetts General Hospital, Boston, out of 692 amputations there were only 180 deaths, a mortality of 26%. This figure he goes on, corresponds reasonably well with that of University College Hospital, but the figures from Parisian hospitals are far worse than those of London for they show a mortality of 60%. Erichsen further quotes Lefort as stating that in Paris from 1836 to 1863, out of 682 amputation cases 58.8% died, and Billroth as stating that at Zurich between 1860 and 1867 46% of his 167 amputations died. At Vienna in 1867 Billroth's amputation mortality was 43.4%, but in 1869 to 1870 it had fallen to 26.08%.

The cause of death was not sufficiently accurately recorded to say how many of these patients died of sepsis, but in later tables of deaths following amputations the probable proportion of

deaths from sepsis may be estimated. Thus in four London hospitals, referring to various periods between 1861 and 1872, Erichsen records that of 631 major amputations, 239 died, 86 from pyaemia and 24 from shock. It is almost certain, however, according to Godlee (1924) that the mortality from "hospital diseases" was much larger than that attributed to pyaemia and the same may be said as regards the other statistics given by Erichsen, since for several of the euphemistic phrases used, modern pathologists would probably have substituted septicaemia.

As regards the cause of hospital diseases the profession was in serious doubt. Nearly everyone agreed that it was the air, or at all events, tainted air which produced sepsis in wounds, but no-one could explain how it was that some wounds healed well in the tainted atmosphere. Opinions differed as to how the air became tainted and still more as to the actual process that went on in unhealthy wounds, and Erichsen's book on "hospitalism", published in 1874, probably reflects quite accurately the orthodox views of surgeons before the time when Lister produced his first paper on the treatment of wounds. As to how to deal with the situation, Erichsen suggested that when pyaemia became established in a hospital it could not be eradicated and the only course was for the hospital to be demolished and everything in it destroyed.

Sir James Simpson (1871) who had also been collecting statistics at the same time, both from hospitals and country practices, produced evidence to show that mortality was much higher in hospitals than in private houses and that it increased in proportion to the size of the hospitals. He advocated the formation of villages of small iron huts to accommodate one or two patients each, which were to be pulled down and re-erected periodically. This was, however, an unattainable ideal but nevertheless his campaigning resulted in many reforms in hospital construction, notably the pavilion system which for a time replaced the corridor system, but was itself in time superseded when a truer knowledge of the cause and route of hospital infection prevailed.

Simpson's view as to how pyaemia was caused differed little from the orthodox view of the time and reflects the confusion that existed. He held that, "The surgical patient was liable to be endangered by the influence of morbific contagious materials from the beds of other inmates, though the blood poisoning which leads on to pyaemia, was generally produced by the inhalation of organic and other materials in the air of hospital wards, but which were not contagious." Simpson was a gynaecologist and remembered most by his discovery and use of chloroform, and it is really another gynaecologist, Semmelweiss, to whom we must turn for some enlightenment on the subject of wound infection.

Semmelweiss, who died in 1865, was assistant at the Lying-in Hospital in Vienna and in 1846 he had noticed that the death rate from puerpural fever was lower in the division reserved for the training of midwives than it was in the division where students were taught. In this division the monthly average on occasions reached a 25 or 30% mortality and Semmelweiss had long puzzled over the difference in the rates in the two divisions. One of his colleagues died of septicaemia following a poisoned wound received while making a post mortem examination and Semmelweiss recognised that the disease was identical with puerpural fever and due to the same cause, infection from without. He first supposed that infective material from a dead body was the only cause of the disease and he at once reduced the mortality in the first division to below that of the second by insisting on the careful disinfection of the hands with chlorinated lime in water. Later he extended his doctrine saying that puerpural fever was caused by decomposed animal organic matter regardless of its origin, but nevertheless, despite the ridicule poured on his views and the unhappy ending of his career, he offered the true explanation of puerpural fever, that it was neither more nor less than blood poisoning occurring in connection with childbirth. Semmelweiss was therefore in two respects the forerunner of Lister. He showed that one particular form of blood poisoning depended upon the contamination of abrasions and external wounds and that neither the size of hospitals nor their crowded wards were responsible for hospitalism, but rather the methods of hospital treatment.

Meanwhile on the other side of the Atlantic and a little earlier, O. W. Holmes published in 1874, his essay on the contagiousness of puerpural fever in which he instanced many cases where practitioners had attended women in labour following autopsies carried out on patients who had died of puerpural fever. Their patients had contracted the fever and died. He also described instances where practitioners had attended cases of puerpural fever and had then proceeded to other deliveries where in turn the women developed puerpural fever and died. In his essay he clearly emphasises the contagious nature of the disease and gives a series of instructions including thorough ablution, changing of every article of dress and the allowing of 24 hours or more to elapse before attending to any case of midwifery.

Thus both Holmes and Semmelweiss demonstrated epidemiologically the mode of spread of puerpural infection and the genesis of epidemics of the disease in hospital, but without bacteriological proof their demonstrations could not be brought to fruition and failed to convince the profession of their true value. It was left to Lister whose researches on inflammation had led him to suspect that decomposition or putrefaction as it was sometimes called, was the cause of suppuration and infection of wounds and that this was

itself caused not merely by the gases of the air, but something carried by the air. Thomas Anderson, professor of chemistry in Glasgow, drew Lister's attention to the work of Pasteur who had shown earlier in his investigations of the causes of wine souring, that micro-organisms and not chemicals were responsible and that these micro-organisms were present in the air. From a study of Pasteur's work Lister deduced that infection in wounds was analagous to putrefaction in wine and he therefore sought for a means of destroying these organisms by using carbolic to kill any bacteria that had already reached the wound, regardless of their source. Such was the dramatic effect of this treatment that whereas the healing of an amputation or a compound fracture without sepsis was a matter for astonishment, now it became commonplace and it is probably true therefore to say that surgery can be divided into two epochs, before Lister, and after.

At first he used carbolic acid and various forms of putty or whitening mixed with carbolic acid and linseed oil. Later he found that weaker acid was satisfactory and caused less excoriation of the skin and after treating some amputations and compound fractures successfully he applied the same principle to the treatment of abscesses, incising them through lint soaked in carbolic acid. The description of his treatment was first published in the Lancet in 1867 under the title of "On a new method of treating compound fractures". In addition to treating the lesions he insisted on everything else connected with them, i.e. dressings, instruments, hands, being treated with the carbolic and he even insisted on an antiseptic atmosphere, a pump producing a fine carbolic spray in the air of the operating room. Later his dressings took the form of gauze impregnated with carbolic and still later of gauze containing cyanide of mercury and zinc, the so-called double cyanide gauze.

The changes that Lister brought about were accepted, and influenced surgery all over the world. As to the effect on the post operative sepsis rate of these revolutionary methods, let me quote from the closing paragraphs of Lister's address to the surgical section of the annual meeting of the British Medical Association in Dublin on 9th August, 1867:- "But since the antiseptic treatment has been brought into full operation ..... my wards, though in other respects under the same circumstances as before, have completely changed their character so that during the last 9 months not a single instance of pyaemia, hospital gangrene or erysipelas has occurred in them". Curiously enough the London School was one of the last to be convinced and it was not until he arrived there himself and took over the chair of clinical surgery vacated by the death of Sir William Fergusson at King's College in 1877, that his methods began to be adopted.

Meanwhile the stimulus made by the advance of bacteriology lead to even greater achievements. Aseptic surgery replaced Lister's antiseptic methods and Schimmelbusch (1894) published in detail the aseptic methods in use at Von Bergman's clinic in Berlin, the principles of which, the steaming of gowns and dressings and the boiling of instruments, persisted into the early years of this century. It is fascinating to read of his description of the necessity for accurate closure of the wound as an antiseptic measure of the first rank, of the use of iodoform gauze plugs or tamponades, of the discarding of the method of irrigation of wounds with antiseptic fluids, using instead sterilised normal (0.75%) salt solution or weak boracic acid for the removal of discharges. Some of the recommendations in the early part of the book, those for instance advising against the stirring up of dust, could well be readapted for use in modern wards, while the rigorous procedure advised of scrubbing the hands followed by rinsing in mercuric chloride or biniodide, persisted until the time of the Second World War. The advance of the aseptic method was undoubtedly hastened by the irritating effect of antiseptics on the hands of the operating staffs but the advance of bacteriological knowledge also played a part. Schimmelbusch describes in great detail the experiments of Fehleisen in Bergman's clinic showing the method by which the streptococci spread in the skin in erysipelas, the researchs of Nicolaier, Rosenbach and Kitasato on tetanus, and those of Rosenbach on the Staphylococcus pyogenes. It should be remembered of course, that it was Ogston* (1882) in Scotland who first identified and named the staphylococcus and differentiated it from the streptococcus. Schimmelbusch also describes the infection caused by B.pyocyaneus producing the so-called blue pus and also the presence of B.coli communis in peritonitis. Thus with these dramatic and momentous changes taking place, hospitalism practically disappeared.

During the remaining years of the 19th century and in the first decade of the 20th century, the aseptic method was developed and increasing importance was laid on the ritual of the operating theatre. Masks were generally used, being first invented by Berger (1899). The use of gloves also became general, but in fact they too had been introduced considerably earlier, Halstead (1913) recording them as being first used in 1899 by the nurses who handed the instruments to the surgeon and later, in 1894, being adopted by his assistant. Records however, of post operative sepsis during this period do not appear to have been kept, and one might presume therefore that the problem was not one which caused anxiety, but the experience of the 1914-18 European war brought fresh problems. Gas gangrene and post operative sepsis again became frequent and for a time it must have seemed that surgery was returning to the pre

* 1882. J.D. Comrie, History of Scottish Med. 2 vols., 1932, Vol. ii p. 555.

Listerian era. Surgeons must have felt that the only solution was to return to the chemical antiseptics of his time because first Wright and then Carrel devised measures on these lines to combat the sepsis.

There was one disadvantage of the aseptic technique, if it could be called a disadvantage, and that was the possibility of a lowered standard of watchfulness on the part of the surgeon and his staff. In Lister's day the occurrence of a stitch abscess would have horrified him, but now with the application of a sterile gauze pad to the wound, cocci from the deeper layers of the skin were able to reach the surface and grow in the stitch tracks, and so into the deeper layers of the wound. Lister's carbolic application prevented this happening. In the immediate pre 1914-18 war period and during the earlier part of the war, stitch abscesses occurred and were apparently accepted. The wound had "gone wrong". During the war with the bad conditions under which wounds occurred and were treated, hospital sepsis increased and no method seemed able to control it. Wright brought out his "hypertonic treatment" which consisted in the constant application to the wound of salt solution of such a strength as was calculated to encourage to the utmost the flow of lymph from the surface. He trusted to the bactericidal power of the lymph and to the use of serum to overcome the organisms which, he said, it was impossible to destroy by any chemical antiseptic in such wounds as are inflicted in modern warfare.

For a time Wright's method enjoyed popularity but it was to a large extent superseded by an "antiseptic" method introduced by Dr. Carrell (1917) at Compiègne. Carrell, helped by Dakin, used a solution containing hypochloride of sodium, polyborate of sodium and small quantities of free hypochlorous and boric acids, and his method was to cleanse the wound, remove foreign bodies, clots, damaged tissue and then to irrigate the wound either continuously or at regular intervals through fine india rubber tubes permanently fixed in the recesses of the wound. The wound was then closed when the operator, judging by the bacterial count in the wound, deemed it safe to do so. This would have pleased Lister but as the war went on and especially towards the end, the popularity of the method waned and more and more surgeons turned to the employment of the less complicated method of primary and delayed primary or secondary suture for the treatment of wounds. The practice was to excise the wound freely and if the bacteriological report was satisfactory and if the wound appeared satisfactory, to sew it up. If however, there was any doubt, that is if the wound was complicated or bacteriological examination showed the presence of dangerous pathogens, the wound was left open and only closed when it appeared safe to do so. This was the delayed primary suture. If the wounds were infected suture was only carried out when healthy granulation tissue had appeared. This was secondary suture. (Fraser 1918, Brit. Journal of Surgery, Vol. 6, page 92.).

From the end of the 1914-18 war until the outbreak of the Second World War in 1939, the question of post operative sepsis became relatively unimportant. Statistics of sepsis in surgical wards are not to be found but accounts of sepsis in domiciliary surgical practice are available. In this period of 20 years the lesions of the First World War were not forgotten. In compound fractures free access to the wound was the rule and mild antiseptics for the washing out of the wounds were employed. I remember myself seeing irrigation of a compound fracture in the Edinburgh Royal Infirmary in 1929, with Eusol (Edinburgh University Solution of Lime) as the irrigating fluid. This particular antiseptic was introduced by Professor Lorrain Smith.

Fashions changed over the question of ligatures. During Lister's life it seemed that silk or linen might replace catgut for sutures in aseptic wounds and during and after the war non absorbable ligatures came more and more into favour. In the mid 20's it appeared that catgut was once more coming into favour, but it was fairly certain that in the presence of asepsis, silk and linen could be used with perfect safety. If however, sepsis occurred then the silk and linen became irritating foreign bodies that had to slough away in the discharge. As regards the remainder of operation procedure, the aseptic technique became standard.

When we look for actual statistics of the period a note appears in the postscript of Godlee's Lord Lister where he describes the status quo (1924) and asks whether results are better or worse than those of 20 or 30 years ago. He quotes:- "Some surgeons consider that there has been little or no improvement since Lister's day, others that his results were better than ours and yet others maintain that year by year the battle against sepsis is fought with greater and greater success, but one and all say that in private practice their cases practically never 'go wrong' whereas in hospital cases do 'go wrong' and stitch abscesses are not unknown. The cause is thought to be two fold, the allowing of probationer nurses to have a practical share in theatre training, and of students to act as dressers. As opposed to this the system in the famous clinics in America, is for the assistants to be highly trained surgeons and the theatre staff permanent. In the Mayo clinic they obtain 98% of primary unions and in the Swiss clinic the proportion 'going wrong' is very small indeed." (Dr. W. Mayo. Professor A. Kocher. Private Communications)

It is interesting at this stage in the history of post operative sepsis to consider how antiseptic principles were applied in midwifery, since despite the fact that the epidemiology of puerpural sepsis was correctly appreciated long before its bacteriology was understood, obstetricians appeared slower than the surgeons to apply antiseptic measures. Cullingworth (1888) at St. Thomas's

Hospital when giving his address at the opening of the session 1888-89, chose as his subject "The state of affairs in puerpural sepsis," and for it he had gathered figures from many hospitals in Europe and the United States, demonstrating the value of antisepsis in reducing the gross amount of puerpural sepsis. The figures he gave, which were impressive, were from hospitals such as the huge lying-in hospital in Vienna where Semmelweiss had worked, and that in Dresden, from hospitals in New York and Boston, Paris, and from St. Thomas's nextdoor neighbour, the hospital in New York Road, and he clearly showed that whereas deaths from puerpural sepsis had been in the region of 50-60 per thousand live births, in some instances they were now as low as 0.7 per thousand. The obstetricians were using antiseptic douches for the perineum and vagina, for the instruments, and the hands of those attending the patient were being washed thoroughly in soap and water, followed by rinsing in mercuric chloride 1:1000. Where a cream was required it was made up of mercuric chloride 1:1000 in glycerine.

Although previously the obstetricians had been slow, it was now their turn to advance whereas surgeons had to wait for the stimulus of the 1939-45 war for a renewal of interest in wound dressing techniques and the prevention of post operative sepsis.

In the early 30's it was established that the organism responsible for most cases of puerpural fever was the haemolytic streptococcus (Ministry of Health, 1932) and the advances in streptococcal typing of Griffith (1934) was of great assistance to pioneers such as the Colebrooks (1935) who were studying puerpural fever at Queen Charlotte's Hospital, London. Smith (1931) in Aberdeen, had already emphasised the role of the attendants as the source of the infection, and this was confirmed by the Colebrooks. Not that this required much confirmation after the observations so long ago of Holmes and Semmelweiss, but the simple advance in knowledge that was established, was that whereas previously the attendant had brought infection from the post mortem room or another case, now attention was focused on the healthy carrier, i.e. those persons who although healthy, carried streptococci in the upper respiratory tract. Thus, of 48 patients with streptococcal puerpural infections for whom a source of infection was found, 24 appeared to have been infected from an attendant, 9 from a healthy household contact and 6 were infected with streptococci they had been harbouring before the onset of labour (Colebrook, D. 1935). This work was carried out for the most part on patients infected outside the hospital, but the epidemiology had an obvious bearing on hospital work. Colebrook (1936) recommended the use of a Chloroxylenol disinfectant as a douche and in a cream for the maintenance of sterility of the hands.

The Ministry of Health Report 1932 and Colebrook (1936) suggested that streptococcal carriers, particularly if they were heavy should be excluded and that routine bacteriological examination of attendants with colds or those who were recovering from respiratory tract infections, should be instituted. Other recommendations were that gloves and masks should be worn and intravaginal manipulations after rupture of the membranes should be avoided. Rigorous isolation measures were also introduced and cases of puerpural fever were removed to isolation hospitals, thus minimising the risk of spread in maternity units. Similarly patients on whom manipulations had been carried out prior to admission, were also kept under observation in isolation, until infection was confirmed or otherwise.

Some work had also been carried out on the infection of wounds in surgical units and it was established that the streptococcus was the most important organism in this respect, although it was suspected, Fleming and Porteus (1919) and Stokes and Tytler (1918-9), that the infection was for the most part conveyed to the wounds during dressing.

We come now to the 1939-45 war and a revival of interest in the prevention of infection in wounds. Apart from the interest taken in the streptococcal etiology of puerpural fever and in the streptococcal infection of wounds, there was little recorded apart from the important observation of Okell and Elliott (1936) in University College Hospital, of the frequency of streptococcal complications in operations on the ear, nose and throat. These two observers, over a period of three years, took swabs of the noses, throats and lesions of patients and of the throats and noses of doctors, nurses, ward maids and other ancillary staff allocated to the wards. Fourteen outbreaks of streptococcal disease were recorded and among the fatalities were 3 deaths from streptococcal septicaemia and bronchopneumonia in young men who had been admitted on account of tonsillitis. Amongst the recommendations to stop the infection and prevent further outbreaks were the introduction of screens, the widening of the space between beds, the use of open-air balconies during night and day, strict isolation, sterilisation by heat of all the bedding and the wearing of masks with cellophane inserts.

As regards streptococcal infection of wounds, Miles (1940) traced the spread of individual serological types of streptococcus round a ward and Spooner (1941) likewise traced streptococcal infection in wounds in a plastic unit and found that up to 25% of the patients acquired streptococcal infections, and that from 55% of the wounds, haemolytic streptococci could be

isolated. In the six months under observation two epidemics of wound infection and one of throat infection caused by haemolytic streptococci occurred. It is interesting to note however, that of the 115 wounds, 100 yielded Staphylococcus aureus, 33 out of 37 of which were coagulase positive, and it is of greater interest that Spooner records that no serious staphylococcal disease was seen. Of the other organisms only Pseudomonas pyocyanea and proteus were seen in any frequency.

These observations led to a re-examination of the methods of dressing wounds and it was realised that indirect contact provided many opportunities for the conveyance of infection from one patient to another. Although a nurse's hands might be washed between dealing with each patient contamination of the dressing or the contents of the dressing trolley could have occurred. The "no touch" technique was therefore introduced in a Medical Research Council Memorandum of 1931 and sterilised dressing forceps were ordered to be used for all manipulations involving the wound, sterile dressings or instruments. In addition, the formation of a team was recommended in which the principal carried out the toilet of the wound, an assistant handed the required articles and even a third attended to the bed, removed soiled dressings and acted as runner. Interest having been thus aroused and material being available, experiments and observations on wound infection followed one another. McKissock, Wright and Miles (1941); Logue and McKissock (1945); Williams, Clayton-Cooper, Howat and Miles (1944-5) all showed that the adoption of such a dressing routine in fact reduced the incidence of added infection with streptococci or staphylococci.

The new dressing routine had one great advantage that only one wound was likely to be exposed at any given time and it also lead to minor but important changes in ward structure. Wash hand basins had to be provided in the wards, since nurses could not be expected to wash their hands as frequently as was necessary if they had to walk considerable distances, (Gissane, Miles and Williams, 1944). A sufficiency of instruments had to be provided to ensure that the nurses would be able to carry out the technique properly. A further development was that of dressing stations and at Birmingham Accident Hospital an out-patient clinic was built in which a large number of small wounds could be examined and the dressings changed with aseptic precautions as rigid as those for larger wounds in the wards (Williams, 1945; Williams and Miles, 1949). Both in hospital out-patient departments and in factory first-aid rooms, the adoption of these methods reduced the incidence of added infection (Clayton-Cooper and Williams, 1945).

Such bacteriological studies greatly helped in the understanding of post operative infections and although there was little or no organised investigation into the extent of such sepsis in the country as a whole, individual studies continued to emerge as particular points were brought to light. Investigations followed several clear routes. Much work was done on the cross infection of burns, much was also done in infectious diseases hospitals and elsewhere on "air-borne" infection and particular attention was paid to infection arising in operating theatres. A real stimulus was given to investigations into post operative sepsis when Devenish and Miles (1939) showed that a surgeon who was a persistent healthy carrier of staphylococci, contaminated wounds through small punctures in his rubber gloves and through the sleeves of his gown when they became wet. This was an important observation and brought to light an avenue of infection which hitherto had not been considered. In addition it became clear that the healthy carrier of staphylococci was as potentially dangerous as the healthy or convalescent carrier of streptococci, but Williams (1946) and others pointed out that a large percentage of normal people carry pathogenic staphylococci in their noses and on their skin and there was therefore this important difference between the streptococcal and staphylococcal carrier. Moreover these carriers of staphylococci simply could not be excluded from operating theatres or wards and techniques had to be devised on the assumption that everyone might be a carrier.

Studies of small industrial wounds of the hands had showed that as with the large war wounds streptococci were not usually the primary infecting organisms. They usually represented added infection often acquired in hospital. Staphylococci on the other hand, were often derived from the patient's own skin and represented "self infection". (Williams and Miles, 1945, 1949). It seemed therefore, that while the prevention of infection should eliminate streptococcal infection of traumatic wounds, it could not eliminate, though it would reduce, staphylococcal infection. When phage typing of staphylococci became available however, it was evident that staphylococci were commonly transferred from one patient to another by hospital cross infection.

It is appropriate now to discuss the new antiseptics since having arrived at the stage where the evidence for the transfer of staphylococci from wound to wound by hospital cross infection can be found, it is of interest to see how the streptococcus particularly, has been eliminated as a cause of wound infection, and the staphylococcus as the "resistant" Staph. aureus, has taken its place.

It was in obstetrics that the "new antiseptics" - the chemotherapeutic or antibiotic drugs - were first used. Colebrook and Kenny (1936) reported their experiments with the first of the sulphonamides and showed that this revolutionary and dramatic drug could greatly lessen the effect of hospital infection. Previously nothing could control streptococcal infection once it had been contracted; now a drug had been produced which appeared to do this. There is no doubt that the incidence of puerpural infection had been falling considerably before the sulphonamides appeared, but within the next few years, puerpural infection was to disappear as a significant cause of maternal mortality. This development was of the greatest importance in medicine because of its widespread application and it was of equal importance in the history of post operative infection. Not only were the sulphonamides of great value in excluding streptococci from surgical wounds, but it was in connection with surgical wounds that the stumbling block of "resistance" was first encountered when Cruickshank and his colleagues in 1942, reported the spread of sulphonamide "resistant" haemolytic streptococci among the wounds in a plastic surgery unit.

Fortunately however, this did not delay the removal of the streptococcus from the field of hospital infection and its elimination was completed by the introduction of penicillin. Nor has the problem of resistant haemolytic streptococci become a major one, but the staphylococcus on the other hand, was first found to be resistant to penicillin in 1942 and has since showed a great ability to develop resistance to each successive antibiotic soon after its introduction; so much so, that in 1952 Clarke, Dalgleish and Gillespie were able to demonstrate staphylococci resistant to no less than six antibiotics.

It was believed at first that the development of drug resistance was due to previous inadequate treatment with an antibiotic and that resistance arose afresh in each individual patient. The experience gained from phage typing has shown that the appearance of the resistant strain is almost always due to re-infection from the hospital personnel or the environment. It was shown, for instance (Barber and Whitehead, 1949) that when patients were admitted to hospital with infection due to sensitive staphylococci acquired outside, they were of many phage types. On the other hand when resistant staphylococci were acquired in hospital, these were commonly of one phage type and that, characteristic of the hospital. Some observers however, have shown that there is a possibility of resistance to erythromycin developing anew in individual patients, (Wise, Voight, Collin and Cranny, 1955).

One of the effects that this question of resistance of staphylococci has had is that of dampening down the enthusiasm of surgeons to branch out into new fields of surgery. Whereas previously the introduction of antibiotics, coupled with advances in anaesthetic technique and blood transfusion methods, had encouraged surgeons to make considerable strides in, for example, thoracic surgery, now there is some hesitation and a demand by the surgeons for the bacteriologists, hospital architects and engineers to rid the hospitals of these dangerous pathogens.

We have come a long way therefore, since Devenish and Miles showed that staphylococci escape through holes in a surgeon's gloves, or since Spooner noted that staphylococci were present in a large proportion of wounds in a plastic surgery unit, but the history of post operative infection in the post war period will not be complete without some reference being made to the other two routes of investigation mentioned previously, namely air-borne and theatre infection.

Prior to the work of Wells (1936) no one had been able to demonstrate adequately that bacteria travelled considerable distances, but in 1935-6 Wells, using a new form of air sampler, showed that bacteria dispersed into the air by coughing, could be carried on air currents for quite long distances and on the basis of his experiments he wrote that air disinfection ought to be able to prevent it. Thus ultra-violet irradiation of the atmosphere, mostly in the United States, was attempted and although impressive results were claimed no attempt was made to carry out tests of a similar nature in this country. On the other hand Harris and Stokes (1945) in a trial of disinfection of the air by glycols, reported a considerable decrease in naso-pharyngeal infections. Interest became concentrated on contaminated dust on the floor of wards and bedding, and it was easy to demonstrate that in wards with infected patients, large numbers of pathogenic bacteria were present in the dust and were disturbed when the floors were swept or the beds made. (Crosbie and Wright, 1941; Garrod, 1944; Rountree and Armytage, 1946; Rubbo, 1948). Colebrook in 1946 made the extremely important contribution from the point of view of post operative sepsis, that further aerial contamination may arise in surgical wards from the bandages and dressings covering infected wounds.

It was natural therefore, with the early demonstration of pathogenic bacteria in dust, that numerous attempts would be made to solve the problem of dust, particularly infected dust in surgical wards, and experiments by van den Ende, Lush and Edward (1940) showed that bacteria in floor dust could be prevented from being dispersed into the air by treating the floor with a light oil.

Methods were then devised for applying oil to blankets and bedclothes, (van den Ende, Lush, Edward 1941; Harwood, Powney and Edward 1944; Loosli, Wise, Lemon, Puck and Robertson, 1946) and similarly this greatly lessened the contamination of air during bed making. In 1944 Wright, Cruickshank and Young reported a great decrease in cross infection by streptococci in a children's measles ward through the new treatment when compared with a control ward and the principle was applied to surgical wards by Rountree (1947) and Clarke, Dalgleish, Parry and Gillespie (1954). Although a reduction in the number of air-borne bacteria was recorded there was unfortunately no noteworthy decrease in the incidence of cross infection.

The oil treatment however, was unsuitable in many ways. The blankets did not appear clean and gave a peculiar feeling when handled. The nursing staff were unhappy about the appearance of the ward. So far as blankets were concerned, more progress was made in another direction. The extent of the bacterial contamination of some blankets was considerable and it was found that not only did ordinary laundering methods fail to disinfect them, but that if sheets, for instance, were disinfected by boiling, they were liable to be re-infected again in the laundering (Church and Loosli, 1953). This led to the investigation of the disinfection of blankets by Quaternary ammonium disinfectants and Barnard (1952) and Blowers and Wallace (1955) published descriptions of successful methods of either disinfecting by these compounds or washing by ordinary methods followed by a disinfectant rinse.

As regards the possibility of air-borne infection in the theatre giving rise to post operative sepsis, interest was naturally aroused by Wells' work on the air-borne transfer of respiratory pathogens and Hart, in the United States (1941) reported a greatly reduced rate in post operative sepsis, particularly in operations on the chest, following the installation of ultra-violet irradiation in his operating room. Gudin (1942) adopted a more practical method of ensuring complete absence of bacteria from the operating room by means of air disinfection and air conditioning. This certainly was a more comfortable way of arranging things as the use of direct irradiation meant that protective eye shields had to be worn by the theatre personnel. Cairns (1939) in Britain suggested from his experience of neuro surgery that air-borne theatre infection was probably commoner than had been supposed and in 1946 Robinson, McLeod and Downie reported two cases of post operative tetanus attributed to dust air borne from a field outside the operating room. Sevitt (1939) attributed two similar cases to dust from building operations and in 1953 the same observer reported a case of gas gangrene due to air-borne dust. Nevertheless although it appeared almost certain that infection of wounds producing post operative sepsis was taking place in theatres, direct evidence was difficult to produce.

Much work was undertaken on this problem and Bourdillon and his colleagues (Bourdillon, Lidwell, Lovelock and others, 1948; Bourdillon and Colebrook, 1946; Girdlestone and Bourdillon, 1951) studied the factors affecting the number of bacteria present in the air of operating rooms. It was clear that the patient's entry often provoked the liberation of very large numbers of air-borne bacteria, giving counts of up to 100 particles per cu. ft., and these commonly took some time to disappear. It was also found that many operating rooms were so designed that contaminated air was drawn into them from other parts of the hospital. Where any artificial ventilation was installed it was generally arranged to suck air from the operating room, if only so that steam from the sterilizers could be removed. But this, coupled with the frequent temperature differences between the operating room and the rest of the building, often had the effect of sucking air into the operating room from nearby corridors or from adjacent treatment rooms. In at least one case such a room was used for the removal of plaster splints from limbs and this is a procedure that may generate very large clouds of air-borne bacteria.

The bacteria found in the air of the operating rooms were hardly ever the pathogenic varieties that cause wound sepsis, but Bourdillon argued that they were useful as indicator organisms in that they were derived from the places and objects (and persons) who might well be reservoirs of pathogenic bacteria. Nevertheless it has proved very difficult to obtain any really precise estimate of the significance to be attached to particular numbers of bacteria in the air of operating rooms. Bourdillon and Colebrook (1946) suggested that the counts of the total number of aerobic bacteria in the air in quiet periods of an operation, should not exceed 10 per cu. ft. when tissues of normal resistance to infection were being exposed, and 2 per cu. ft. when burns, brain or other highly susceptible tissue was involved. These figures reflected experience of what could reasonably be achieved in well designed operating rooms, and with proper clothing of the patient and staff. There was, and still is, no evidence that the figures can be regarded as "safe" levels, and a great deal more work is needed to establish the true usefulness of counts of bacteria in the air.

To control the bacterial contamination of the air in operating rooms, Bourdillon made two principal recommendations. One was to adjust the ventilation, and the other was to regulate the clothing and activities of staff and patient.

There seemed no doubt that the best arrangement was to bring clean filtered air, humidified if necessary, into the room under sufficient pressure to overcome any inward air currents from other sources. Air could be brought in at ceiling height and it was

found possible to obtain 10-20 changes per hour without any perceptible draught. This rate of air change is generally sufficient to prevent contamination remaining in the theatre air.

Two recent reports lend considerable support to Bourdillon and Colebrook's ideas (Blowers, Mason, Wallace, and Walton, 1955; Shooter et al., 1956). In both cases an undue prevalence of sepsis had been observed in clean surgical wounds and in both cases high bacterial counts were found in the air of the operating room. Blowers and his colleagues were led to an extensive revision of the general hospital aseptic technique, including the conversion of the operating room ventilation to a system designed to preclude contamination of the theatre air from the rest of the hospital. In the work of Shooter et al. this latter change was all that was attempted. In both hospitals there was a dramatic fall in the incidence of post operative sepsis.

The work of Bourdillon and Colebrook (1946) illustrated the gross contamination that can result from removing dressings from infected wounds and from transferring a patient from a trolley to the operation table, especially if he is covered with unsterilized blankets or blankets used on his bed in the ward. The extent to which inadequate face masks allow bacteria from the mouth and nose to reach the air is now well known (e.g. Rooks, Cralley and Barnes, 1941) and the work of Duguid and Wallace (1948) demonstrated that ordinary clothing, even when it is covered by the conventional type of operating-room gown, can be a source of numerous air-borne bacteria.

The situation then in the summer of 1957 was that bacteriologists and surgeons were aware that post operative sepsis was present to a greater or lesser degree in hospitals throughout the country and that Staph. aureus was playing a large, if not the major, part. The presence of large depots of Staph. aureus had arisen from the breeding of resistant strains, and it had been shown that personnel in hospital were carrying these strains in their noses, on their skins and on their clothing. No one however, was quite clear as to the extent of the sepsis. The impression generally was that it was becoming more common. There have been reports of outbreaks of exceptional severity with sepsis rates of between 10 and 37% and effects on patients varying from being obliged to remain in hospital for a few extra days to several months. Often the inconvenience is negligible but bad cases have occurred where sinuses have continued to discharge and patients have returned to hospital to have a subphrenic abscess evacuated or have even died. These figures from outbreaks of infection are probably reliable because they were collected at times when the results in the units concerned were carefully noted. Attempts to observe sepsis rates in non epidemic times have been less satisfactory and general enquiry to surgeons yields widely

divergent answers. Some admit that they are uneasy about sepsis while others pooh-pooh the situation and maintain that there always will be sepsis. Others strongly deny that there is any at all. Analysis of clinical records is valueless because only the grossest kind of sepsis is recorded in them. In the group hospital covered by this study, there was until a few years ago, a septic block which was always well occupied by septic surgical cases. It was converted to administrative offices but no other provision was made for the isolation of septic cases and since then these cases have remained in the wards. It was felt, therefore, that only by planning an investigation for the specific purpose of investigating the amount and duration of the sepsis that a true estimate could be obtained.

A few investigations of this type have already been made in single hospitals. In Britain, Clark (1957) reported a sepsis rate of 13.6% causing a mean extra stay in hospital of 8.1 days. Jeffrey and Sklaroff (1958) found that 26.1% of clean operation wounds developed sepsis, 9.8% being serious. Burnett, MacDonald and Timbury (1958) recorded a sepsis rate of 7.6%. There are similar reports from Australia, Canada and the United States. These reports suggest that sepsis rates throughout the country may be much higher than is generally realised. The present study was therefore planned to give information of the incidence of wound sepsis and the length of stay of septic cases in the group hospital. Opportunity was also taken to study the relationship between wound sepsis and some of the circumstances that might determine its development. These were nasal carriage of Staph. aureus in the patient before operation, presence or absence of Staph. aureus on the skin at the site of operation, age and sex, nature and duration of the operation, length of incision and presence or absence of drainage tubes.

Since the beginning of the study much work has been carried out, principally in the United Kingdom and the United States, to learn more about post-operative sepsis. The extent of the sepsis has been demonstrated by reports such as that of the Public Health Laboratory Service, 1960. This report presented the results of a two year study covering 21 hospitals in England and Wales and described the findings in over 3,000 operations. Sepsis rates varied from 4.7% in one hospital to 21.8% in another giving an average of 9.7%. The mean extra stay in days on account of sepsis was 7.3, and the authors of the report calculated the cost of such increased bed accupancy as over £3 million per annum. Sixty per cent of the septic cases were infected by Staph. aureus. The report gave interesting details of the incidence of sepsis following different operations. The highest sepsis rate after clean operations was for cholecystectomies, 21.0%, followed by radical mastectomies, 15.0%. The lowest rate, 2.0% followed orthopaedic operations.

Rountree, et al. (1960) working in Australia, published details of an investigation into post-operative sepsis which covered a period of six months in a general hospital. A post-operative sepsis rate of 14.0% was found in clean wounds and of 68.0% in dirty wounds: again the principal infecting agent was Staph. aureus. The authors found that the increased length of stay in hospital on account of sepsis, reduced the effective use of beds by 5.0%.

A third investigation published was that of Gillespie et al. (1961). This was the completion of a previous study, Gillespie et al. (1959), and together with it represented observations over a period of $4\frac{1}{2}$ years in a general hospital. The importance of this study lay in the evaluation of certain measures adopted to control the sepsis. While the authors agreed that suppuration in closed wounds was nearly always traced to theatre infection, they showed that open wounds (drained) often became colonised by Staph. aureus and provided a good index of total ward cross infection by staphylococci. The susceptibility of open wounds to cross infection varied according to their size, the amount of discharging and soiling by urine or faeces, and the time taken to heal. Measures to lessen the incidence of cross infection included nasal prophylaxis, a Polybactrin spray and thorough disinfection of vectors. The cross infection rate was lowered to about one third of its former extent and the incidence of other staphylococcal complications such as post-operative pneumonia, was greatly diminished.

In the United States, Caswell et al. (1960) published an analysis of 7,691 operations covering 16 different operational procedures in the period 1956-59. The staphylococcal sepsis rate varied from less than 1.0% in operations such as appendicectomy, simple mastectomy, to 1.0% in Caesarian section and rose to 7.6% in radical mastectomy and 9.7% in pneumonectomy. The authors comment on the frequency of the appearance of Staph. aureus of phage type 80/81 and state that had this particular type not been present then the total Staph. aureus infection rate would have been under 1.0%. In a further publication, Caswell et al. (1960), the authors commented on staphylococcal infection of surgical wounds and described the importance of the part played by the phage type 80/81. They stated that the question of whether or not hospital related staphylococcal infection has increased in the past 10 years is no longer a significant one. The important question now is what is being done to study its mechanism and epidemiology, and to devise techniques which will prevent it.

A further discussion of the importance of this phage type of Staph. aureus 80/81 is given by Nahmias et al. (1960), also in the United States, in a description of a series of post-operative infections taking place in a general hospital, which were traced to a particular surgeon who was found to be a disperser of the three associated strains, 80/81; 80/81/52/52A and 80/52/52A. Cultures yielding these strains were obtained from his face, hands and nose. When the surgeon was rested from operating work the infection ceased, but the curious fact emerged that the surgeon himself just as quickly ceased to be a carrier. When he again took up operating he continued for a while to be free from the carrier state, but immediately he came into contact with phage type 80/81 through a patient he once more became an active disperser and no reason could ever be found for his becoming so. The paper further comments on the difficulties of tracing infection and cites the fact that in vitro it is possible for phage type 80/81 to be converted to either 80/52/52A or 80/81/52/52A, and 80/81/52/52A to 80/81.

Loewe and Cohen (1961) in Brooklyn, pointed to the fact that development of cardiovascular surgery has brought in its wake the menace of blood stream infection by resistant staphylococci. They emphasised that since 50.0% or more of serious staphylococcal complications are acquired in hospital, rigid prophylaxis must be practised and gave a list of measures which should be undertaken for the prevention of post-operative sepsis.

As regards the epidemiology of hospital infections by staphylococci, Burke and Corrigan (1961) in Boston published the results of investigations in a surgical ward of 1958 and 1959. They attempted to find the exact reservoirs of any epidemic or endemic strains and noted that fluctuations took place in the ward staphylococcal content. They concluded that these were such as one would expect from a large group of individuals living together. They also found that strains were not perpetuated by hospital plant or hospital personnel who were not harbouring active lesions, but the important individual was the patient with an active septic lesion who constantly and heavily seeded his immediate environment. They found that antibiotics had no effect on the total incidence of carriers nor did they influence the changing distribution of carriers in the wards cited.

In the United Kingdom, work recently has tended to be less concerned with statistics of post-operative sepsis than with measures concerned with its control and an evaluation of the part played by antibiotics. Some authors however have attempted to throw light on the spread of Staph. aureus of the antibiotic

resistant type outside hospitals and Buhr continuing a report of 1952 on infections of the hand from the Oxford Accident Service found in 1957 that in 81 (30.0%) of 267 out-patients penicillin resistant staphylococci were present. Previously in 1952 he had found no trace of penicillin resistance in 82 out-patients. Of 187 out-patients from the general population who had not had penicillin for the hand infection under review, 27.0% grew penicillin resistant strains of Staph. aureus as compared with 37.0% of the patients who had had penicillin therapy.

As regards technical improvements designed to play a part in the control of sepsis the majority of suggestions have originated in the United Kingdom. Frisby (1959) gave details of the TEGO series of compounds. These are amino acids of high molecular weight and the author reported encouraging results from experiments with an emulsion for hand cleansing, a lotion for pre-operative skin disinfection and a spray to be used for washing down walls and ceilings of operating theatres and for sluicing operating theatre floors.

Bateson (1959) and Stratford et al. (1960) described the use of Soframycin as an intra nasal therapy designed to have a sterilising effect on the mucosa of the nasal passages. Bateson tried a throat lozenge and intra-nasal spray in an attempt to limit secondary infection following the common cold, but Stratford et al. made a significant addition to the armament for the control of nasal carriage of staphylococci by pointing out that a deep nasal swab may pick out up to 17.0% more nasal carriers than the usual vestibular swab. Moreover they tested several of the nasal applications in current use and showed that a Soframycin (framycetin + gramicidin) spray cleared the nose of staphylococci much more quickly and thoroughly than the others tested.

Caplan (1959) drew attention to the importance of organisms other than staphylococci in post-operative infection and particularly instanced Ps. pyocyanea and B. proteus in genito-urinary wards. Disinfection of blankets with quaternary ammonium compounds has no effect on these organisms and he was able to terminate a long standing infection in a male surgical ward caused by Staph. aureus, Bacillus proteus and Ps.pyocyanea, by having the blankets disinfected by formaldehyde vapour at a slightly raised temperature in vacuo. The process in no way harmed the blankets or caused any irritation to the patients.

The importance of infection with Ps. pyocyanea was further instanced by Sussman et al. (1960) who described an outbreak caused by this organism, in an orthopaedic ward. The discovery of the method of the infection was interesting, the organism being first isolated from a bucket of water used for wetting the plaster of Paris bandages in the plaster room. Removal of the bucket however, did not bring the outbreak to an end. The organism was then recovered from the cellulose wadding (wood-wool) which was used as padding under all plaster casts. Finally it was considered that the organism was reaching the wounds in water which had been expressed from a wet plaster bandage and had become contaminated by passage through the infected cellulose wadding. Oozing and bleeding may also help to form a nutrient bridge by which organisms migrate from the wadding to the wound. This experience pointed to the importance of cotton wool, wadding and all such material being sterilised before being brought into the theatre or plaster room and it also drew attention, like Caplan's article, to the importance of organisms other than Staph. aureus in causing infection.

Forbes (1961) drew attention to the use of a direct antibacterial method of preventing post-operative sepsis in a study lasting for over four years. He showed how the sepsis rate in a general hospital was reduced from 6.7% to 1.8% by the use of a "Polybactrin" spray. This, containing Neobacrin, Polymyxin B and Bacitracin, is sprayed into each layer of the wound as it is closed. Forbes attributed the fall in the rate entirely to the use of the spray and noted that when the use of the spray was discontinued for two months, the rate again rose. When the spray was re-introduced, the sepsis rate again fell.

Rubbo et al. (1960) in discussing the vehicles of transmission of airborne bacteria in hospital wards, came to the conclusion that wool fibres played no part in this, but that organisms either were carried about free on air currents or attached to microscopic fibres of cellulose, so called "fibre-nuclei". These findings resulted from an investigation of hospital dust which they found consisted not of wool fibres, but mostly of cellulose. Cellulose fibres made up 60.0% of the fluff on floors and 90.0% of that caught in an air filter. There were two kinds of fibres, large fibre particles and microscopic, but the degree of contamination of the air in a ward bore no relation to the degree of polution by visually detectable fibres. Visible woollen fibres or droplet nuclei did not seem to play a significant part in the airborne contamination of wards.

Elek and Fleming (1960) experimenting with the penicillin compound "Celbenin", reported a new technique in the control of staphylococcal sepsis. Since Gould (1958) had shown that hospital atmospheres contain appreciable amounts of penicillin as demonstrated by air sampling, thus accounting for the exclusion of penicillin sensitive staphylococci from the noses of hospital personnel, they argued that the deliberate introduction into the atmosphere of an antibiotic active against all strains of staphylococci, should completely abolish nasal carriage of the organism. With this achieved and the most fruitful source of the organism occluded, sepsis would decrease. Accordingly they experimented by spraying different concentrations of "Celbenin" into the atmosphere of a baby nursery in a London hospital, and they were able to reduce nasal carriage of staphylococci considerably in the babies. Infection of umbilical and rectal areas was also reduced as compared with a control ward. The authors concluded that this was an economic and simple way of reducing the nasal reservoir of staphylococcal infection.

As regards other studies in the antibiotic field, that of Maccabe et al. (1961) and of Barber et al. (1960) must be mentioned. Maccabe et al. drew attention to the importance of Erythromycin resistant strains, and described how they are able to gain access to the hospital and slowly permeate through all units. They found that 91.0% of all Erythromycin resistant strains, isolated in a 400 bedded hospital over a two year period, were of the same phage type and concluded that there are a number of these strains capable of existing in an Erythromycin resistant form, and it is a matter of chance whether these are introduced into a hospital environment. Establishment and spread of such organisms is encouraged by the use of antibiotics. They advocated limiting the use of antibiotics, frequent bacteriological examinations to locate these strains, and the use of other means of preventing cross infection.

Barber et al. suggested a new approach in the problem of cross infection by staphylococci, namely by opening an attack on the multiple resistant strains themselves. They argued that the selection of drug resistant staphylococci in hospital may have resulted also in the selection of strains of high virulence. They succeeded, by limiting the use of penicillin, by a deliberate "double antibiotic" policy and by restriction of the use of antibiotics for prophylactic purposes, in reversing the trend of resistance formation in the hospital where they were experimenting. After a period of $1\frac{1}{2}$ years they found that the number of penicillin sensitive strains of staphylococci had increased and the number of penicillin-tetracycline resistant strains had decreased considerably.

PART I

The incidence of infection and bacteriological findings

Methods and Materials

The patients were men and women admitted either as emergencies or from the waiting list to the general surgical wards of two hospitals, A of about 270 beds and B of 200 in a provincial town of England, which are combined and administered as a group hospital and serve a population, urban and rural, of 150,000. Four surgeons were concerned, three general and one with a preference for orthopaedic work. With the exception of three types of operation - genito-urinary, those involving the rectum, and open fractures - no attempt was made to select the patients. The method therefore was, with these exceptions, to accept all admissions during a certain period - 15th September, 1957 to 30th November, 1960 - in the study. The reason for not including the exceptions was that it was considered that they might show an undue tendency to become septic from the nature of the site or lesion. The wards were six in number, one male and one female in each hospital and a male and female convalescent ward in hospital B. In hospital A the average was 22 beds to the ward, in hospital B, 25.

The method of recording patients was as follows. Male and female patients admitted to the surgical wards were examined and a record made of their names, ward, hospital number, age, sex and date of admission on a special form. This form was the one devised by the Public Health Laboratory Service working party for use in the survey. A nasal swab, moistened with broth, was taken on admission or as soon after as possible and in addition a second swab similarly moistened with broth, was rubbed over the skin at the site of operation. Results of culture of these swabs were entered on the form. At operation the surgeon or assistant added to the form the date and certain other details required for the survey, i.e. the type of operation, time taken, length of incision and a forecast of the number of days he expected the patient to remain in hospital if the wound healed by first intention and recovery was uneventful. He also added the type of skin antiseptic applied before operation.

A swab, moistened with broth, was taken of the wound at first dressing, every few days if the wound was septic and a final swab just before the patient was discharged from hospital. When the patient left hospital the date was recorded and a note made of the state of the wound. Four variations were noted: (1) clean, (2) clean but infected, i.e. a perfectly clean wound yet pathogens isolated on swabbing, (3) septic but not infected, i.e. a septic wound but no pathogens isolated and (4) septic and infected, i.e. the wound showing one of the major signs of sepsis and a pathogen

isolated. Records of wound swabs and the state of the wound with the organisms isolated were made on the reverse side of the form. Cultural methods were as follows. The swabs, which were on wooden applicators, were inoculated onto the surface of agar plates containing 5% horse blood and the plates incubated at 37° C. overnight. The swab head, after inoculation of the plates, was broken off into 10 ml. of 6% salt broth. This was incubated for 48 hours and inoculations then made onto blood agar plates. Staphylococci were tested for coagulase production both by the rapid slide method using undiluted human plasma and where slow doubtful reactions had occurred, by the tube method using 1 ml. of a 1:10 dilution of plasma, adding 5 drops of an overnight culture of staphylococci in broth and incubating for 6 hours at 37° C. Coagulase positive staphylococci were phage typed at the Staphylococcus Reference Laboratory, Central Public Health Laboratory, Colindale.

The skin antiseptic applied before operation was one of four in common use in both hospitals and in each case was the one with which the surgeon had been accustomed to work for many years. These antiseptics were:-

1.	Cetavlon + Watery cetavlon, i.e.	an application of Cetavlon ½% in alcohol 65.6%; followed in 30 seconds or so by a wash of cetavlon 1% in water.
2.	Spirit	Industrial Methylated spirit (95% alcohol)
3.	Euflavine	Euflavine 1% in spirit (70% alcohol)
4.	Cetavlon	Cetavlon ½% in alcohol (65.5%)

As however, I wished to compare results obtained after the use of iodine as a preoperative antiseptic with those following the use of the usual applications, all surgeons were asked to use iodine 2% in spirit (70% alcohol) for certain periods. From 1st April, 1958 to March, 1959 it was agreed that each surgeon should use iodine for the same fortnight in every month and his usual antiseptic for the remaining fortnight. Iodine and non-iodine sessions therefore were organised simultaneously in both hospitals and the scheme worked well. A calendar was prepared for a year from the date of commencement of the scheme so that the theatre staffs in both hospitals were aware of what was going on, the pharmacists had similar time tables, stocks of freshly prepared

iodine were always supplied to the theatres before the sessions began, and a surgeon had no need to remember when an iodine session was due to begin or end, the theatre staff automatically arranging this for him.

There were one or two difficulties. One surgeon disliked using the cautery when a spirit lotion had been applied and preferred to wash over the area with watery cetavlon some 30 or 45 seconds after the application of iodine. Another insisted on using industrial spirit on malignant breasts likely to have x-ray therapy later and in operations on varicose veins; but with these exceptions the sessions were well maintained and the routine followed.

As regards examination of the surgeons' gloves the method adopted was for the surgeon to strip off his gloves, put them in a sterile dish, which was then brought to the laboratory. Swabs moistened with broth were rubbed on the inside of the gloves and the swabs broken off into 10 ml. quantities of 6% salt broth. It was felt that dilution in this amount of broth would help to neutralise any anti-bacterial effect of the powder in the gloves. This procedure was abandoned after a time and an easier and more precise method was used. In this the author went to the operating theatre and swabbed the gloves of the surgeon, the assistant and occasionally those of the theatre sister or nurse. The surgeon would first pull off one glove as far as the fingers, exposing the palm of one hand and the inside surface of the glove. A swab, moistened with broth was then rubbed over the palm, another over the inside of the glove and two swabs were taken of the other palm and glove. Swabs were similarly taken of the other personnel involved and on return to the laboratory the swabs were broken off into 10 ml. quantities of 6% salt broth. This was cultured for 48 hours, and subculture then made on to blood agar plates. Some swabs were also taken of the gloves of one of the surgeons and a sister after the use of Phisohex for scrubbing up as it had been found that the hands of these two were frequently contaminated with Staph. aureus.

Blanket contamination was studied by using the method originally described by R. E. O. Williams; the sweep plates were made of the top blankets of the beds in the six wards of the two hospitals. In addition, for comparison, sweep plates were also made of the top blankets in five other wards, two orthopaedic and three medical. Efforts were made to carry out the same number of sweeps on each blanket with the sweeps following the same pattern.

This was not always possible for example if a cradle covered a limb under the blanket, nevertheless the sweeps were kept as uniform as possible. Some mattresses in each ward were also examined by sweep plates. Three surveys were made of the blankets of the wards mentioned. The first was in February, 1959 before any attempt was made to disinfect. The second was in May, 1959 after the Lissapol Cirrasol process had been in operation in hospital A for 2½ months and a commercial laundry using Arquad had been disinfecting the blankets of hospital B. The third was in October, 1959 when the disinfecting process was well established in both hospitals and blankets were being disinfected on discharge of every patient or after every three weeks for long stay patients.

For the air contamination studies the author was fortunate in being able to enlist the help of Dr. R. E. O. Williams, Director of the Air Hygiene Laboratory at the Central Public Health Laboratory, Colindale. Using a slit sampler from the Air Hygiene Laboratory, observations were made lasting for 3 hours each during operating sessions in both hospitals and routine working in surgical wards of both hospitals.

The controlled trial of nasal disinfection was carried out in the same wards in which observations had been made since the beginning of the study and for this a nasal disinfectant cream, Naseptin, was made available by Imperial Chemical Industries Ltd. This was supplied in unlabelled tubes together with a similar quantity of control tubes of identical pattern containing the inert base only. It was previously decided that one set of these tubes was to be labelled with the word "Even" and the other set with the word "Odd". Small pieces of adhesive tape were used for this on which the words were printed with indelible pencil. They were then issued to the wards concerned in the trial, each ward receiving a box of 50 "even" tubes and a similar number of "odds". The ward staff was not told which tube contained the Naseptin and which the inert cream and the staff distributed the tubes according to the hospital number of the patient, those patients with an even number were given the "even" tubes and those with an odd number the "odd" tubes. In a short time the author found it easier to distribute the tubes himself at the time of the initial swabbing as some explanation to the patient of what was being done was found to be necessary.

The procedure as regards swabbing was precisely as had been carried out previously, the patient's both nostrils being swabbed with one swab moistened with broth and when this had been done the

appropriate tube of cream, odd or even, was given to the patient who was then shown how to squeeze out a small quantity onto the tip of the little finger. The finger was then inserted into each nostril in turn, a fresh piece of cream for each nostril, and the cream then spread evenly over the whole of the inside of both nostrils. The patient was asked to do this four times in the day and a second nasal swab was taken later, at the same time as the wound swab.

It was essential for the accuracy of the trial to get the initial swab as early as possible and the cream inserted equally speedily and with waiting list cases this usually took place within 24 hours of admission. In fact many cases were dealt with on the same morning as admitted, but usually those admitted in the afternoon and evening were seen next morning. Emergencies were a little different and whereas week night emergencies operated on during the night were seen and dealt with next day, those operated on between Saturday afternoon and Monday were not seen until Monday morning and although a hospital number had been allocated by Monday morning, up to 48 hours on occasions elapsed before swabbing and insertion of cream took place.

There were other difficulties. One found a high proportion of really old people having operations, either waiting list or emergency, and some of these old people found it difficult to understand what was required and occasionally forgot to insert the cream according to the schedule. Some found it difficult to insert the finger tip and I felt that on occasions the cream was not being applied evenly and efficiently in the nostrils. Another type of patient with whom one had difficulty was the gastro-duodenal operation which required suction and had a Ryles tube in the nasal passage for 48 hours to assist in emptying the stomach, although many of these patients managed to insert the cream despite the presence of the rubber tube. Finally one had the really ill patient to deal with who had perhaps an intravenous drip in each arm, and in these cases the nursing staff helped by inserting the cream on a swab. An important fact learned from this study was that if mass nasal disinfection of noses is to be employed as a prophylactic measure, it is unwise to rely wholly on the nursing staff to remind old people when cream should be inserted or to insert the cream in the nostrils of really ill people. Nurses in a busy ward have too much work to do and cannot be expected to carry out extra duties such as this. Besides with staff constantly changing it is impossible to expect a nurse to remember to instruct her relief about such duties. These difficulties were reflected in the results as it was found on analysis that in 74 Naseptin users colonization by Staph. aureus took place or was not eradicated. In the majority of these this was due to one or other of the factors mentioned above. This is referred to later.

Records

The method of initiating the special form has already been described but certain details require to be added here. Organisms isolated from the nose and skin swabs when the patient was first seen were entered on the form and strains of Staph. aureus and Strep. pyogenes were stored. Staph. aureus strains were submitted for phage typing. The date of taking the post-operative swab varied. In the majority of cases which healed by first intention the swab was taken after the stitches had been removed and the patient was ready for discharge but if sepsis occurred and the wound required to be inspected earlier then a wound swab was taken by one of the ward staff. Next day the incident would be reported to the author who would then again see the wound and take a swab. When sepsis did occur swabs were taken at regular intervals and the results were recorded together with a progress report on the state of the wound. In the Public Health Laboratory Service survey the requirements were that at least 50% of the wounds should be seen by the bacteriologist and surgeon. In this study the author saw and swabbed all wounds and then discussed the results with the surgeons concerned. The exact procedure adopted was that blank forms were held by the ward sister, who on admitting a patient, filled in the name, number, age and surgical condition of this patient, i.e., the operation to be performed and placed the form in a special folder. The author made a round of the four surgical wards each morning and by looking in the folder was able to see which cases had been admitted and then proceed to the nasal and skin swabbing of each. Usually this was preceded by a word with the sister or staff nurse and the work was soon completed. The forms then went to the theatre with the patient's notes and after the operation the surgeon, registrar or houseman completed the operation details, when it was returned to the ward and replaced in the folder. The author inspected them on his daily round and removed the form from the folder when the patient was discharged. Later when bacteriological results, phage typing, etc. were completed, the form was filed until required for analysis.

Results

A pilot survey took place in August 1957 when some 30 cases were investigated but the main study did not begin until mid September, 1957 and from this date until 30th June, 1959, there are records of 1788 operations, complete with clinical details. The word "septic", as explained earlier, refers to clinically manifest disease in the wound and "infected" means the presence of pathogenic bacteria, including as pathogens coagulase positive staphylococci, haemolytic streptococci, faecal streptococci and coliform bacilli. Included in the coliform group were E.coli, Klebsiella species, Proteus, paracolon bacilli and Pseudomonas pyocyanea.

TABLE I

General incidence of sepsis and infection with pathogenic bacteria

Both Hospitals

Clinical state of wound	No. of wounds and percentage of total	Bacteria isolated from wounds during convalescence shown as percentages of septic infected or clean infected wounds			
		Staph. aureus		Coliform organism alone	Other pathogenic bacteria
		Alone	With Other pathogens		
All wounds	1788				
Septic, infected	213 11.9	115 54.4	50 23.4	33 15.5	15 7.04
Septic, non-infected	17 0.9				
Clean, infected	228 12.7	105 46.0	11 4.8	69 30.9	43 18.7

Of the 1788 wounds examined, 230 (12.8%) showed signs of sepsis during healing and 213 (11.9%) of these were both septic and yielded pathogenic bacteria. 228 (12.7%) were clean and healed perfectly but on swabbing a pathogen was isolated. Of the pathogenic

bacteria isolated from the septic wounds by far the commonest organism was Staph. aureus, this organism being found in no less than 115 (54.7%) wounds on its own and in addition being associated with other pathogens on 50 (23.5%) other occasions. Next came E.coli and this organism on its own was isolated on 33 (15.4%) occasions. Of the other pathogens B.proteus accounted for 6 cases, Strep. pyogenes for one, anaerobic streptococci for two and there were a few cases where groups of three pathogens occurred, P.pyocyanea, E.coli, B.proteus, Strep. pyogenes or Staph. aureus being isolated in various combinations. Mention will be made of Streptococcus pyogenes later as an interesting feature occurred when this organism was found contaminating the environment but not apparently causing wound sepsis.

A feature also worthy of note is that there were 17 cases (Table I) where clinical sepsis was present without a pathogen being isolated. In sixteen of these the only organism isolated was a non coagulase producing staphylococcus but in several instances although coagulase was not produced when tested for by the tube method the sensitivity pattern of the organism resembled that of the hospital type Staph. aureus, resistance to tetracycline, chloramphenicol or penicillin being encountered. This experience gave one the feeling that production of coagulase was not an infallible test of pathogenicity.

TABLE II

Details of Staph. aureus and pathogenic bacteria associated with it in 213 septic infected wounds

Comparison of Hospital A and B

	Total septic infected wounds	Staph. aureus alone	Staph. aureus with other organisms				
			E.coli	Strep. pyogenes	Ps. pyo-cyanea	Proteus	Others
Hospital A	105	64 61.0	19 18.1	2 1.9	1 0.95	2 1.9	-
Hospital B	108	51 47.3	17 15.7	-	-	3 2.8	6 5.6
Both Hospitals	213	115 54.0	36 16.9	2 0.94	1 0.47	5 2.4	6 2.8

E.coli appeared to be the only organism, apart from Staph. aureus which was isolated with any frequency. The other pathogens such as proteus or Ps. pyocyanea played an extremely minor role in the infection of surgical wounds in this hospital group.

TABLE III

Details of pathogenic bacteria other than Staph. aureus in 213 septic infected wounds

Comparison of Hospital A and B

	Total Septic Infected Wounds	E.coli	Proteus	Strep. pyogenes	Anaerobic Strep.	Others
Hospital A	105	14 9.0	3 1.9	-	-	1 0.65
Hospital B	108	17 15.8	3 2.8	1 0.93	2 1.9	5 4.6
Both Hospitals	213	33 15.5	6 2.8	1 0.4	2 0.9	6 2.8

The same remarks as for Table II apply to the analysis of Table III. The organisms under "other" in both tables comprised combinations of the various pathogens apart from Staph. aureus.

TABLE IV

Analysis of types of sepsis with pathogenic bacteria isolated

Clinical state of wound	No. and percentage of total		Staph. aureus				E.coli alone		Other pathogens	
			Alone		With other pathogens					
Total septic	230									
Discharging pus	134	58.2	66	28.6	34	14.7	20	8.6	10	4.3
Stitch abscess	32	13.9	18	7.8	6	2.6	6	2.6	1	0.43
Serous discharge	28	12.1	11	4.7	6	2.6	7	3.0	-	
Healing by granulation	27	11.7	17	7.3	1	0.43	-		3	1.3
Marginal erythema	9	3.9	3	1.3	3	1.3	-		1	0.43
			115	54.7	50	23.5	33	15.4	15	6.5

The severity of the sepsis in different patients varied considerably. In some instances only some marginal erythema indicated that infection had taken place, in others the wound broke down and discharged large quantities of pus, more than half of the

wounds being in this category, while lesser degrees of infection such as stitch abscess, serous discharge or healing by granulation occurred in almost equal amounts. There is no outstanding feature in the association of the type of organism infecting the wound with the type of lesion but it is noteworthy that Staph. aureus was responsible for only minor degrees of infection, i.e. stitch abscess, serous discharge, healing by granulation or marginal erythema in 49 (20.0%) cases. These were all hospital type staphylococci insensitive to penicillin or tetracycline yet producing lesions of relatively minor importance.

TABLE V

Incidence of sepsis and infection with pathogenic bacteria

Comparison of Hospitals A and B

	Septic infected		Staph. aureus				E.coli	
			Alone		With others			
	Hosp. A	Hosp. B	Hosp. A	Hosp. B	Hosp. A	Hosp. B	Hosp. A	Hosp. B
Total septic	113	117	64	51	24	26	16	17
Discharging pus	68 60.2	66 56.4	37 57.9	29 56.9	17 70.9	17 65.5	11 68.7	9 53.0
Stitch abscess Serous discharge Healing by granulation Marginal erythema	45 39.8	51 43.6	27 42.3	22 43.2	7 29.2	9 34.7	5 31.2	8 47.0

Both hospital A and hospital B are acute hospitals and handle the same type of work, the differences being that the volume of work in B is somewhat larger, the theatre is of a

different design and the wards are more separated than in hospital A. Hospital A is a much older building whereas B, built more recently, has separate, single story pavilions with a good deal of space between them. Another difference is that in Hospital B many wounds are occluded by adhesive dressings and not touched until the time for removing the stitches. In hospital A many of the wounds are covered by loose bandages and the wounds are dressed daily. This is referred to later. On analysis the results are remarkably similar, the number of wounds discharging pus and the pathogenic species being isolated showing very little difference between the two hospitals.

TABLE VI

Incidence of pathogenic bacteria in clean infected wounds

Comparison of Hospitals A and B

	Total clean infected wounds	Staph. aureus	Staph. aureus and others	E.coli	Strep. pyogenes	Proteus	Others
Hospital A	104	47 45.2	3 2.9	39 37.5	12 11.6	1 0.96	2 2.0
Hospital B	124	58 46.7	8 6.5	30 24.2	14 11.3	12 9.7	2 1.6
Both Hospitals	228	105 46.0	11 4.8	69 30.3	26 11.4	13 5.7	1 0.44

It is interesting to consider the organisms isolated from clean wounds. These wounds had healed perfectly by first intention within the time forecast by the surgeon and although a few were sterile on swabbing, the majority gave a growth of non-pathogenic staphylococci. A certain number however, 228 (12.7%) yielded pathogenic bacteria. The distribution in both hospitals was similar but there was an interesting new feature in that Strep. pyogenes was found infecting the wound surface on 26 (11.5%) occasions whereas it had only been isolated on one occasion from septic infected wounds.

TABLE VII

Incidence of sepsis following different types of operation, the number of septic infected and clean infected wounds shown as percentages of total of each type of operation

Operation	Hospital A			Hospital B		
	Total	Septic infected	Clean infected	Total	Septic infected	Clean infected
Appendix	199	10.5	9.5	192	12.0	7.3
Hernia	165	6.1	13.9	142	9.2	21.8
Gall bladder	64	26.6	14.0	84	26.2	13.1
Gastrectomy	49	12.2	16.3	78	14.1	11.6
Other abdominal	126	15.8	14.2	116	17.5	19.0
Breast	74	27.0	8.0	44	9.1	
Veins	57	15.8	15.8	75	5.4	
Thyroid	23	-	21.8	47	2.1	6.3
Laminectomy	-	-	-	14	-	14.3
Sympathectomy	5	-	20.0	23	13.0	8.7
Menisectomy	-	-	-	31	-	12.9
Other orthopaedic	2	50.0	-	51	5.8	3.9
Miscellaneous	56	16.1	10.7	71	18.6	10.0

Table VII shows the proportion of the wounds that were septic infected and clean infected, following different categories of operation. As might be expected the highest rates of infection followed operations of the more serious type, e.g. those in the gall bladder area where the sepsis rate was 26.6%, but the sepsis rate in operations on the breast - radical mastectomies - was also high in hospital A. Similarly, other abdominal operations, excluding those on the appendix and gastrectomies, had also a high rate. It is interesting to note that thyroidectomies where there is a considerable bleeding area necessitating ligation of many vessels provided only one case of septic infection in 70 operations. With the exception of breast operations and those to relieve varicose veins, sepsis rates in both hospitals were not significantly different.

TABLE VIII

Incidence of sepsis following different types of operation

Isolation of predominating pathogens shown as percentages of septic infected or clean infected wounds

Both Hospitals

Type of operation	Septic infected	Staph. aureus alone or with others	E.coli alone	Clean infected	Staph. aureus alone or with others	E.coli alone
Appendix	42	57.1	38.6	34	32.9	51.2
Hernia	22	87.5	3.9	52	51.9	30.9
Gall bladder	38	74.6	16.3	20	79.8	14.6
Gastrectomy	16	83.3	8.3	17	52.8	24.6
Other abdominal	38	85.0	7.5	40	55.2	29.0
Breast	24	85.0	15.0	6	42.6	8.3
Veins	12	88.4	5.6	27	48.4	25.7
Miscellaneous	20	88.4	11.5	13	100.0	-
Total	212			209		

Types of operation such as thyroidectomies, menisectomies, etc., where septic infected or clean infected wounds were few, have been omitted.

As the sepsis rate following different types of operation was reasonably similar in both hospitals with the exception of two - operations on the breast and those for varicose veins - and in order to keep the size of the table within reasonable proportions, the percentage isolations of the important pathogens in the two hospitals have been aggregated in one table, Table VIII.

The figures in this table show that Staph. aureus was the predominating pathogen and it seemed that the distribution was fairly evenly spread among all types of wounds. It did not seem to matter whether the wounds were septic infected or clean infected. The same could be said of whether the Staph. aureus was found alone or in combination with other organisms. As regards E.coli the situation was somewhat different. When the wounds were of the septic infected class, appendix operation wounds produced the largest number of instances where a pure growth of E.coli was obtained - and this was seen in both hospitals - but it was surprising to find E.coli being isolated from septic wounds following breast operations and those for varicose veins. One associates E.coli with operations involving the abdomen, usually following incision of the bowels. A high percentage of clean infected wounds following vein, hernia and simple orthopaedic operations showed surface contamination with E.coli. So did other clean abdominal operations. E.coli obviously contaminated the environment in surgical wards just like the staphylococcus.

TABLE IX

Length of stay in Hospital

Both Hospitals

State of wound		Number of patients with records available	Mean days in hospital over forecast
Septic infected*		203	+ 9.9
Septic non-infected		17	+ 3.6
Clean infected*		226	- 0.1
Clean		1330	- 0.5
Total		1776	
Septic infected 203	Discharging pus	120	+ 13.05
	Stitch abscess	23	+ 4.4
	Serous discharge	23	+ 6.7
	Healing by granulation	32	+ 5.8
	Marginal erythema only	5	+ 6.2
Total		203	+ 9.9

*The records of patients who died are excluded from the analysis.

When the surgeon had completed the operation he was asked to enter on the form the predicted stay of the patient in hospital. This was usually some standard figure, e.g. 10 days for an appendix, 14 for an uncomplicated abdominal operation and so on. If the case had some complicating feature which might delay discharge of the patient allowance was made by extending the forecast. Cases which developed sepsis usually remained in hospital until healing took place or at least until the patient was fit enough to go home or be removed to a convalescent ward. For analysis all patients who died or who were kept in hospital for some other reason (medical or non medical) were excluded. The results are given in Table IX. For patients with healthy and uninfected wounds the surgeon's estimates as might be expected were accurate, the average stay in hospital being less than one day shorter than predicted. Similarly infection of clean wounds appeared to have no effect on the length of stay. For all patients with septic wounds there was an excess stay of over 9 days and from the analysis it can be seen that the presence of pus meant on the average an excess stay of over 13 days.

Deaths

Altogether 40 patients died, but in only one case could sepsis be said to have played any part in causing the death of the patient.

PART II

The study of various factors possibly concerned with sepsis

In order to develop the study and examine factors which it was thought might throw light on the source and route of infection, further investigations were undertaken. In the first place the details of all operations were examined and the various factors, age, sex, etc. analysed to find if any possible relationship existed with the sepsis rate. Meanwhile as the staphylococcus was obviously the important pathogen dominating the scene, an attempt was made to find out as much as possible about the strains of Staph. aureus infecting the wounds, their relation to strains in the noses of patients on admission and afterwards, any possible relation to staphylococci carried on the skin and finally an attempt was made to relate the acquisition of staphylococci in the nose by patients to the length of time spent in the ward.

RESULTS

TABLE X

Various factors associated with sepsis, septic cases for each factor given as percentages of total operations.

		Hospital A			Hospital B		
		Total Ops.	Septic infected	Clean infected	Total Ops.	Septic infected	Clean infected
Total operations		820	13.8	12.7	968	12.1	12.8
Sex	M.	418	17.5	11.5	488	13.5	14.2
	F.	402	9.9	13.9	480	10.6	11.5
Age	0-29	187	9.1	9.6	206	5.8	8.3
	30-49	274	10.2	15.3	322	10.6	9.6
	50+	359	19.0	12.3	440	16.2	17.3
S.aureus in nose	+	210	22.9	15.3	248	10.5	13.3
	-	610	10.6	11.8	720	12.6	12.6
Surgeon	Cons.	572	16.1	13.2	766	13.1	12.9
	Reg.	185	9.2	10.3	167	7.8	15.0
	H.S.	63	7.9	15.9	35	11.4	-
Duration of operation in minutes	0/30	188	9.5	8.5	302	6.3	7.3
	31/60	405	11.1	12.3	398	14.1	12.3
	61+	227	12.3	16.7	268	15.7	19.8
Incision in inches	0/6	544	8.3	12.9	799	10.8	13.0
	6+	276	24.6	12.3	169	18.3	11.8
Drainage	+	166	31.4	13.8	277	22.4	8.3
	-	654	9.3	12.4	691	8.0	11.7

Of the various factors studied to find any possible association with sepsis and presented in Table X, drainage, increased age, length of incision are all prominent. This is apparently inherent in the conditions governing operations in older people as the operations are generally of a more serious nature, take longer, i.e. an hour and more, more often require drainage and normally require a long incision. Operations of this nature tend to have a higher sepsis rate. The fact of the consultants having a higher sepsis rate is clearly a condition of their carrying out the more serious type of operation. As regards nasal carriage of Staph. aureus, this definitely appears to be associated with sepsis but a further analysis will be available later. Again apart from minor differences the figures in the table are similar for both hospitals.

TABLE XI

Staphylococci in the nose on admission

Phage Group	Hospital A	Hospital B
I	70	88
II	40	41
III	29	47
IV	1	2
Miscellaneous	16	19
Mixed	29	17
Not typeable	21	26
*Total	206	240
Number of phage types	122	114

*A few strains were inadvertently not sent for typing thus explaining the discrepancy between the total strains examined and the total noses carrying Staph. aureus

Examination of the nasal flora of patients on admission showed that 458 (25.6%) were carrying Staph. aureus. Swabbing took place as soon as possible and in a small number of cases this was done within an hour or so of admission. Usually, however, swabbing was done on the morning after admission, i.e. within 24 hours but in emergency cases, particularly at weekends, or in cases admitted for observation before operation intervals of 48 hours to over a week elapsed before a swab was taken. The results for both hospitals are given in Table XIV and show, as one would expect, no great difference in the phage groups. In all 122 different types were isolated in hospital A and 114 in hospital B.

TABLE XII

Percentage phage type distribution of staphylococci from septic infected and clean infected wounds

Comparison of Hospitals A and B

Phage group	Phage type	Septic infected		Clean infected	
		Hosp. A	Hosp. B	Hosp. A	Hosp. B
I	80, 52/80, 52A/52/80	38 43.7	51 66.3	15 28.8	34 55.7
	Others	14 16.1	4 5.2	4 7.7	1 1.6
II		3 3.4	1 1.2	-	1 1.6
III		19 21.8	6 7.8	7 13.5	3 4.9
Mixed		2 2.3	2 2.6	4 7.7	1 1.6
Miscellaneous		1 1.1	-	3 5.8	2 3.3
No reaction		5 5.7	4 5.2	14 26.9	19 31.1
Not known		5 5.7	9 11.7	5 9.6	-
Number of wounds with staphylococci		87	77	52	61

As can be seen from Table XII the great majority of wounds both septic infected and clean infected gave growths of Staph. aureus of one of three phage types 80; 52/80; 52/52A/80; the larger percentage of isolations being in Hospital B. Isolations of Group II strains were scanty in both hospitals. There was also relatively fewer of Group III and other types of Group I. Hospital A had fewer of the three main strains but more of Group I others, III others, mixed and untypeable strains. There was no known reason for this.

TABLE XIII

Relation of sepsis to nasal carriage of staphylococci

		Patients with: Staph. aureus in nose		No Staph. aureus in nose	
		Hosp. A 210	Hosp. B 248	Hosp. A 610	Hosp. B 720
Numbers and percentage with staphylococcal sepsis		40 19.0	21 8.4	51 8.3	56 7.7
WITH WOUND STAPH. AUREUS (Figures are shown as percentages of numbers with Staph. sepsis)	Same as nose strain	17 42.5	6 28.6		
	Doubtful same strain	3 7.5	1 4.8		
	Not known	4 10.0	4 11.1		
	Different	16 40.0	10 47.6		
	Total	40	21	51	56

In Table X it was shown that the percentage of sepsis in nasal carriers of staphylococci was more than double that of non-carriers in hospital A and slightly less in hospital B. This is shown in a more detailed analysis in Table XIII. Of 210 nasal carriers in hospital A, 40 (19%) had staphylococcal sepsis. In slightly less than half of these the wound strain was the same as

the nasal strain. But of these the majority of cases were where the strains were of Group I and particularly one of either 80; 52/80; 52/52A/80; or combinations of these. In hospital B the number of nasal carriers was 248 and 21 (8.4%) developed staphylococcal sepsis. In less than one third of these however, was the wound and nose staphylococcus the same.

In hospital B the percentage of sepsis in the nasal carriers was practically the same as in the non-carriers of either hospital.

TABLE XIV

Relationship of nose and skin carriage of staphylococci to staphylococcal wound sepsis

Comparison of Hospital A and B

Septic infected and clean infected wounds

	Hospital A	Hospital B	Total
Total patients examined	256	282	538
Patients with S.aureus on skin	62 24.2	62 22.0	124 23.1
Septic infected	31 12.1	23 8.2	54 10.0
*Skin, and wound strains same phage type	5 16.1	6 26.1	11 20.4
*Nose, skin and wound strains same phage type	3 9.7	-	3 5.6
Clean infected	40 15.6	39 13.8	79 14.7
‡Skin and wound strains same phage type	4 10.0	-	4 5.1
‡Nose strain and wound strains same phage type	2 5.0	-	2 2.6

* ‡The numbers are expressed as percentages of septic infected and clean infected wounds respectively.

When the survey had been in progress for some time it was felt that some observations ought to be made on the bacteria of the skin at the site of operation, and any relationship investigated that might exist between nose and skin colonization by staphylococci and staphylococcal wound sepsis. I could find only one reference to such an investigation having been made and it was felt that the result might be of some value. In the great number of cases this was done at the time of taking the original nose swab, and another swab moistened in broth was rubbed several times, rotating it meanwhile, on the skin where the incision was likely to be made. Skin swabbing was carried out over a period of 9 months and in all 517 cases were so swabbed. The percentage isolations of Staph. aureus from the skin were somewhat lower than isolations from the nose. The percentage where Staph. aureus from the skin and wound were the same was lower than that for nose and wound relationship (Table XIII), and it was unusual to find cases of staphylococcal sepsis where the skin, nose and wound staphylococci were of the same phage type.

TABLE XV

Phage types of nasal staphylococci in relation to length of time in hospital

Phage Group	Time in hours of stay in hospital					Total
	4	24	48	72	Longer	
I	14	77	23	12	29	155
II	6	44	13	4	9	76
III	8	37	11	7	13	76
IV	-	6	3	-	-	9
Miscellaneous	8	18	7	2	5	40
Mixed types	3	22	10	2	7	44
Not typeable		28	7	3	5	43
Not known		5			1	6
Total	39	237	74	30	69	449
80; 52/80; 52/52A/80 as percentages of Group I	14.2	29.8	30.4	41.7	48.2	

Table XV shows the effect on the nasal flora of stay in a surgical ward. I should explain that in most cases swabbing of the noses of patients took place within 24 hours of admission and in some, within as short a time as 4 hours. With patients admitted at the weekend, mostly emergencies, 48 hours often elapsed

before the swab could be taken but there were other instances - patients admitted for observation or pre-operative treatment - where 72 hours or longer elapsed before swabbing was carried out. It was entirely fortuitous therefore that the taking of nasal swabs was as shown above. It provided an opportunity of observing the effect of stay in a surgical ward on the nasal flora.

The figures for both hospitals have been grouped together and it can be seen that as time elapses so the percentage of three distinct types, 80; 52/80; 52/52A/80; increases. These three types were those most commonly found infecting wounds in this particular hospital group (Table XII). If there is a connection between nasal carriage of staphylococci, particularly of "hospital " types and wound infection it is clear that measures to prevent the nose from being colonized with these types should be put into effect very soon after admission.

PART III

Measures to combat the sepsis

After the study had been in operation for a few months it became clear that the sepsis rate in operation wounds was high, far higher than it should have been and this together with incidents in other wards and departments of the hospital, e.g. drip wounds becoming septic and yielding staphylococci on culture, the finding in medical wards of large numbers of sputa containing staphylococci, a high rate of infection with staphylococci of urinary tract operations, two post mortems showing staphylococcal endocarditis, septic spots on the babies in the maternity wards and chronic staphylococcal infection among the nursing staff, showed that there was an invasion of both hospitals by staphylococci. It seemed important therefore, while the study was proceeding, to find out something about the sources of sepsis and as records were being kept of surgical operations an excellent opportunity presented itself for attempting to assess the efficacy of the pre-operative antiseptics used by the surgeons. Each surgeon had his own technique and a particular antiseptic but to see whether the introduction of iodine would lessen the amount of sepsis an experiment was devised whereby each surgeon used iodine and the antiseptic of his choice for alternate fortnights. The experiment went on for a year and Tables XV to XIX show the details of operations following the use of different antiseptics and iodine and the effect of the introduction of iodine on the sepsis rate.

Towards the end of the iodine experiment investigations were carried out in the theatres of both hospitals into hand carriage of staphylococci by members of the surgical and nursing staff, swabs being taken of both hands of the surgeons and nurses concerned and of the inside of their gloves. This lasted from January, 1959 to November, 1959 and information was gained about the extent of hand carriage of staphylococci. Phisohex, a new antistaphylococcal hand lotion was then introduced into general use and its effect noted. The results of these obeservations are in Table XX. Meanwhile as it had been found that there was considerable staphylococcal contamination of ward blankets measures for disinfecting blankets were begun and surveys carried out throughout 11 wards in both hospitals on three occasions, in February, May and October of 1959. Mattresses were also examined. The results are in Tables XXI and XXII. Finally in October of 1959 an investigation was made into the extent of air pollution of both hospitals by staphylococci. The results are in Tables XXIII to XXVI.

RESULTS

TABLE XVI

Total operations. Sepsis in relation to pre-operative antiseptic used. Figures for variations of sepsis and clean categories shown as percentages of total operations for each antiseptic.

Both Hospitals

		Cetavlon + watery cetavlon	Spirit	Euflavine	Cetavlon	Iodine + watery cetavlon	Iodine
Total operations	1788	575	110	485	176	168	274
Septic infected	213 11.9	61 10.6	27 24.5	53 10.9	16 9.0	21 12.5	35 12.8
Septic non infected	17 0.9	6 1.04	1 0.9	2 0.4	3 1.7	2 1.2	3 1.1
Clean infected	228 12.8	88 15.3	16 14.5	60 12.4	15 8.5	13 7.7	36 13.1
Clean	1330 74.4	420 73.04	66 60.0	370 76.3	142 80.6	132 78.6	200 73.0

Of the 1788 patients studied, 230 (12.8%) showed signs of sepsis and of these 213 (11.9%) were both septic and yielded pathogenic bacteria (Staph. aureus in over 70% of cases). These septic cases

are grouped to the pre-operative antiseptic used in Table XVI. Of the six antiseptics used only iodine or iodine + watery Cetavlon was used by all four surgeons. The other antiseptics represent the work of individual surgeons and the rates for Cetavlon + watery cetavlon, Euflavine, iodine + watery cetavlon and iodine do not differ greatly from the overall sepsis rate. The figures for spirit are derived from fewer operations, and of these a large number were major operations in elderly people and therefore especially liable to sepsis.

TABLE XVII

Lighter type of operation. Sepsis in relation to antiseptic used.

Antiseptic	Appendix		Hernia		Varicose veins		Orthopaedic	
	A	B	A	B	A	B	A	B
Cetavlon + watery Cetavlon	110	11 10.0	96	8 8.3	37	1 2.7	39	2 5.1
spirit					30	7 23.3		
Euflavine	129	12 9.3	120	4 3.3	19	1 5.2	5	-
Cetavlon	54	5 9.2	18	1 5.5	6	2 33.2	48	3 6.2
iodine + watery Cetavlon	29	3 10.3	26	4 15.3	26	1 3.7	11	-
iodine	69	12 17.2	47	3 6.2	14	3 21.3	23	1 4.3
Total	391	43 10.9	307	20 6.4	132	15 12.1	126	6 4.7

A. Total operations of one type using different antiseptics

B. Numbers septic infected with percentage B of A

TABLE XVIII

Heavier type of operation. Sepsis in relation to antiseptic used.

Antiseptic	Gall Bladder			Gastrectomy			Other abdominal		
	A	B		A	B		A	B	
Cetavlon + watery Cetavlon	55	13	23.6	40	16	40.0	82	11	13.4
spirit									
Euflavine	48	12	25.0	37	5	13.5	77	20	25.9
Cetavlon	13	1	7.6	12	1	8.3	17	5	29.4
iodine + watery Cetavlon	15	7	46.6	11		-	20	2	10.0
iodine	17	4	23.5	27	3	11.1	46	7	15.2
Total	148	37	25.0	127	25	19.6	242	45	18.1

A. Total operations of one type using different antiseptics.

B. Numbers septic infected with percentage B of A.

In Tables XVII and XVIII where a break down of the numbers of operations into types was made, it is evident that there is a good deal of irregular variation in the sepsis rate in different types of operation and with different antiseptics. No doubt a

good deal of the variation was due to the small numbers of operations as for example, in varicose veins following Cetavlon or iodine and gall bladders following iodine + watery Cetavlon. In addition, in the figures for appendicectomy those cases where an abscess was found at operation were included and it is difficult to imagine any particular antiseptic preventing subsequent breakdown in the wound in these cases but it is also evident that there is no skin antiseptic that is associated with results clearly and consistently better than others.

TABLE XIX

Effect of iodine on sepsis rate

Non-iodine sessions	Numbers of operations	Numbers of septic and infected wounds	
17. 3.58 - 30. 3.58	47	9	18.8
14. 4.58 - 27. 4.58	65	8	12.3
12. 5.58 - 25. 5.58	41	4	9.7
8. 6.58 - 21. 6.58	55	5	9.0
7. 7.58 - 20. 7.58	38	2	5.2
1. 9.58 - 14. 9.58	6	-	
29. 9.58 - 12.10.58	37	1	2.7
27.10.58 - 9.11.58	55	8	14.5
24.11.58 - 7.12.58	54	10	18.5
22.12.58 - 3. 1.59	36	2	5.5
18. 1.59 - 1. 2.59	54	3	5.5
16. 2.59 - 5. 3.59	59	8	13.5
Total	546	60	10.9
Iodine or iodine followed by watery Cetavlon			
31. 3.58 - 13. 4.58	42	11	28.1
28. 4.58 - 11. 5.58	50	4	8.0
26. 5.58 - 7. 6.58	45	2	4.4
22. 6.58 - 6. 7.58	42	2	4.7
21. 7.58 - 3. 8.58	-	-	
15. 9.58 - 28. 9.58	28	2	7.1
13.10.58 - 26.10.58	49	5	10.2
10.11.58 - 23.11.58	46	9	19.1
8.12.58 - 21.12.58	36	6	16.6
4. 1.59 - 17. 1.59	59	8	13.5
2. 2.59 - 15. 2.59	42	4	9.5
Total	439	53	12.0

Although a proportion of operations such as radical mastectomies and Trendelenburg's operation for varicose veins were not included because of the dislike of one surgeon for the use of iodine in these cases, the selection in the series is a wide one and covered practically the work of one year in both hospitals. After a bad start with a high percentage of septic cases from 31st March, 1958 to 13th April, 1958 it appeared for several months that iodine was effecting some improvement but the rate soon levelled out and at the end of the series it was clear that the introduction of iodine had made no difference to the sepsis rate. Further, it could be said that the figures indicate that it does not matter whether iodine or one of the other skin antiseptics are used. This does not necessarily indicate that skin antisepsis in general is useless. After all if these skin preparations are equally good one would not expect to find any difference in the sepsis arising after their use.

TABLE XX

Isolation of Staph. aureus from gloves.

Date	Surgeon	Swabs	Sterile	Staph. aureus	Micrococci	Others
28 Jan. 1959 to 2 Nov. 1959	Mr. B	84	67	1	9	7
	Asst. W	71	46	1	24	-
	Mr. C	52	13	7	32	-
	Mr. D	4	4	-	-	-
	Asst. S	12	-	1	11	-
	" V	16	-	-	16	-
	" T	27	6	4	17	-
	" X	4	4	-	-	-
	" P	12	2	2	8	-
	Nurse Y	12	4	4	4	-
	Mr. A	27	1	14	12	-
	Asst. Q	48	13	-	33	2
	Sister O	20	3	7	10	-
	" L	16	4	-	12	-
Total		405	167 41.2	41 10.1	188 46.4	9 2.2
After introduction of Phisohex						
3 Nov. 1959 to 27 Nov. 1959	Mr. A	37	34	1	2	-
	Sister O	16	15	-	1	-
	" L	8	8	-	-	-
	Asst. Q	4	4	-	-	-
Total		65	61 92.3	1 1.5	3 4.4	-

The numbers for the brief experiment when gloves were stripped off by the surgeons and sent down to the laboratory were too small to be of any value but of 16 gloves examined none produced Staph. aureus and 10 yielded non-pathogenic micrococci.

The fact that one surgeon Mr. B. and assistant W. produced a large number of sterile gloves is noteworthy. The powder used as a glove lubricant was in general use in hospital A and the swabs were broken off into 10-12 ml. of broth to dilute any carry over of powder into the broth. But other surgeons and assistants using the same kind of powder produced many gloves that were not sterile. What is interesting is that the two who produced the largest number of sterile gloves were the only two who immersed and rinsed their hands and forearms in spirit after scrubbing up and then allowed the spirit to dry on their hands before powdering. This is the method described by Price (1951) and recommended by him as the best method of hand preparation before operation.

An extremely interesting change took place when Surgeon A, Sister O, Sister L and Assistant Q agreed to try Phisohex instead of soap when preparing for operations. 92.3% sterile gloves resulted and Staph. aureus was isolated only once.

Although Smylie (1959) used Tween 80 to neutralise any Phisohex carried over on to plates in his glove contamination experiments it was felt that dilution of the swab in large amounts of broth would probably be sufficient to reduce the amount of Hexachlorophene carried over to negligible amounts. The amount of broth into which the swabs were broken off was increased to 15 ml. and subculture was made after 48 hours in case growth of staphylococci was slow.

TABLE XXI

Total top blankets yielding Staph. aureus

Survey	Date	Total beds in 11 wards	Total top blankets yielding Staph. aureus	
1.	Feb. 1959	257	148	57.5
2.	May 1959	257	121	47.0
3.	Oct. 1959	257	118	45.9

Blankets were found to be heavily contaminated with Staph. aureus, the top blanket usually giving most colonies on the sweep plates. In the surveys of February, 1959 and May, 1959 the commonest phage types were 52/52A/80 or related patterns such as 52/80 but by October, 1959 the single 80 phage type constituted more than 80% of the types found. A slight decrease however was apparent in the total numbers of blankets contaminated over the period.

TABLE XXII

Contamination of Mattresses

Ward	Date of sampling	Mattresses yielding Staph. aureus	Predominating phage types
1	15. 5.59	0/2	-
	28.10.59	0/3	-
2	15. 5.59	1/2	N.T. (1)
	21.10.59	1/3	80 + (1)
3	21. 5.59	1/3	80 + (1)
	20.10.59	0/3	-
4	22. 5.59	0/1	-
	18.10.59	2/4	70 + (2)
5	15 5.59	1/3	75 + (1)
	19.10.59	2/4	80 + (2)
6	26.10.59	0/4	
7	13. 5.59	3/3	52/52A/80 (1) 52/80+ (52A) (1)
	12.10.59	1/3	80 + (1)
8	11. 5.59	2/2	29/29 + (1) 80 + (52/52A) (1)
	15.10.59	2/4	80 + (1) N.T. (1)
9	12. 5.59	1/3	52A/79 (1)
	16.10.59	1/3	80 + (1)
10	7. 5.59	1/3	80 (1)
	14.10.59	1/4	6/747/53/75/83/ +
11	6. 5.59	0/3	-
	13.10.59	2/2	53 (1) 29/52 (1)

It is not generally appreciated that mattresses can harbour pathogenic organisms but although the total number examined was relatively small it was clear that a large proportion were contaminated by Staph. aureus of the phage types found in infected wounds, type 80 and related patterns predominating.

TABLE XXIII

Air contamination of theatres

Time started	Duration minutes	Cu.ft.	Count (cols. per cu.ft.) General	Count (cols. per cu.ft.) Staph. aureus	Phage types present
Hospital B					
9.32	7	42	30	0.071	
9.40	"	"	30	0.20	
9.52	"	"	21	0.19	
10.08	"	"	27	0.048	71 :4
10.20	"	"	35	0.048	80 :1
10.30	"	"	21	0.048	52/80 :1
10.41	"	"	19	0.095	53+ :1
10.51	"	"	17	0.048	3C + :1
11.24	"	"	27	0.048	N.T. :2
11.41	"	"	26	0.071	
11.48	"	"	34	0.071	
11.54	"	"	36	0.071	
Hospital A					
9.54	5	30	18	0.033	
10.14	10	60	17	0.033	
10.26	10	"	27	0.100	
11.07	10	"	23	0.067	80 :2
11.20	7	42	31	0.19	6/7/47/53/53/75 :2
11.27	7	"	15	0.048	29/52/52A/79/80/ 54+ :1
11.40	"	"	17	-	
11.53	"	"	16	0.024	N.T. :1
12.06	"	"	12	0.048	29/52/52A/79/80/ 54+ :1
12.22	"	"	17	0.071	
12.38	"	"	32	0.071	
12.52	"	"	13	0.048	

TABLE XXIV

Air contamination of surgical wards

Both Hospitals

Time started	Duration minutes	Cu.ft.	Count (cols. per cu.ft.) General	Staph. aureus	Phage types present
Hospital A					
10.30	60	60	8.0	0.26	
"	"	"	9.2	0.29	80 + :3
11.40	65	65	11.5	0.18	52/80 + :2
"	"	"	8.8	0.18	N.T. :3
12.45	55	55	10.7	8.18	
Hospital B					
9.22	60	60	15.5	0.29	
10.30	"	"	22.0	0.42	All 52/80
11.30	"	"	10.5	0.66	

Tables XXIII and XXIV are concerned with the isolation of Staph. aureus from the air of the operating theatres and wards of both hospital, using a slit sampler operated by the Air Hygiene Unit of the Central Public Health Laboratory, Colindale. The air contamination in both theatres and wards was heavy and this is not surprising considering the amount of contamination present in the blankets and mattresses.

PART IV

A trial of nasal disinfection

The study had now lasted for over two years and some interesting information had begun to emerge. Interim examination of the quarterly sepsis rate had shown, perhaps, a slight decrease but it was clear that no dramatic fall was taking place in spite of the fact that blanket disinfection had been in vogue in both hospitals for over a year, hand treatment using Phisohex had been introduced into both theatres, great care was being exercised by the nursing staff when handling infected wounds - the dressings being disposed of into grease proof bags - and as far as possible isolation of suitable cases of sepsis was taking place, the cases being sent to a neighbouring isolation hospital.

In the meantime one had been impressed by figures published by Williams et al. (1959) in describing the results of their investigations into wound sepsis in a London hospital. Williams and his colleagues found, inter alia, that patients who were or became nasal carriers of staphylococci had three times as much post-operative staphylococcal wound sepsis as those who were never carriers, and that in roughly half the cases the sepsis was due to a staphylococcus of the same phage type as was found in the nose. Since many of the patients became nasal carriers before they developed wound sepsis it seemed possible that self infection from the nose was important in the aetiology of septic lesions. One of the points of interest that had emerged so far from the study being described here, was that in hospital A at any rate, twice the amount of sepsis occurred in nasal carriers of staphylococci as compared with non-carriers. Further in both hospitals the longer patients remained in a surgical ward the more often one was able to isolate from noses, strains of Staph. aureus of the same phage types as those infecting the wounds. Was it possible that both nose and wound were being infected from the environment or was it in fact what Williams and his colleagues suggested, namely that self infection of wounds from the nose was occurring? There was one way of exploring this particular aspect of nasal carriage and it was decided to embark on a controlled trial of nasal disinfection of patients in the same surgical wards where the original investigations had been carried out and to observe the effect upon the sepsis rate. It was considered that if self infection from nose to wound was taking place then disinfection of the nose ought to have some effect on the sepsis rate.

Some attempts have been made in this direction already. Gillespie and his colleagues (1959) included nasal disinfection as one of the measures examined in their attempts to prevent wound infection and they considered it had value but in addition to the nasal disinfection they made several modifications to the ward routine during their studies. It was decided in the trial, the description of which follows, to make nasal disinfection the sole alteration in the routine of the wards.

Some description of the arrangements for the trial have already been given (page 6) but it might serve to repeat the principal details. The patients were, as before, men and women, either routine waiting list or emergency cases admitted to the same wards in which the observations on the sepsis rate had been carried out. The tube of nasal disinfectant cream was given to patients whose hospital number ended with an even digit and a tube of control cream to those where it was odd. The tubes were identical in appearance and were labelled by a piece of adhesive tape on which "odd" or "even" was written. The identity of the odd and even tubes was not disclosed to the sister or nursing staff on the wards, and in fact was only known to the hospital pharmacist and bacteriologist until the study was over. The trial began in January, 1959, ended in October of the same year and altogether 850 patients were admitted to it. The allocation of patients to the treated or non treated divisions by making use of the hospital number resulted in exactly half of them being given the Naseptin and the other half the control cream.

RESULTS

TABLE XXV

Incidence of sepsis and infection

Total number of patients 850		
Number and percentage developing:-		
Sepsis with infection	66	7.7
Sepsis without infection	16	1.8
Infection without sepsis	163	19.2

Of the 850 cases 66 (7.7%) became clinically septic and infected and 163 (19.2%) were clean and infected. 16 cases (1.8%) were septic but not infected. The sepsis rate was thus slightly lower than that found in the 1788 cases described earlier (Table I) and less than that found in the Public Health Laboratory Service report (1960).

TABLE XXVI

Bacterial species found in wounds

Clinical state of wound	Number of wounds	Number and percentage with:-				
		Staph. aureus alone	Staph. aureus + other pathogens	Esch. coli alone	Other pathogens	No pathogens
Septic	82	28 34.1	11 13.4	19 23.1	8 9.7	16 19.5
Clean	768	72 9.3	5 0.6	62 8.0	24 3.1	605 78.7

The percentage of the septic cases yielding Staph. aureus (47.5%) either alone or with other organisms is considerably lower than previously (Table II) and also lower than in the Public Health Laboratory Service report (1960). Since the Naseptin prophylaxis was aimed only at controlling staphylococcal infection, sepsis due to other organisms has been ignored in the remaining analysis.

TABLE XXVII

Incidence of Staph. aureus sepsis and infection in relation to nasal carriers

Nasal Staph. aureus		Naseptin treated					Controls				
On Admission	Subsequently	No.	Numbers and percentage with				No.	Numbers and percentage with			
			Staph. aureus sepsis		Symptomless Staph.aureus sepsis			Staph. aureus sepsis		Symptomless Staph.aureus sepsis	
-	-	260	12	4.6	11	4.2	189	2	1.05	7	3.7
+	-	86	2	2.3	7	8.1	34	2	5.8	2	5.8
Total non carriers at second swabbing		346	14	4.0	18	5.2	223	4	1.7	9	4.0
+	+ different type	12	1	8.3	2	16.1	25	3	12.0	4	16.0
-	+	37	5	13.5	9	24.3	95	10	10.5	14	14.7
+	+ same type	25	1	4.0	4	16.0	70	2	2.5	18	25.7
Total carriers		74	7	9.4	15	22.7	190	15	7.8	36	18.9
*Total patients		420	21	5.0	33	7.8	41	19	4.6	45	10.8

*17 patients who died before observations could be made are excluded from this table.

There was practically no difference in the total Staph. aureus sepsis rate between the Naseptin-treated group (5.0%) and the controls (4.6%). This is surprising because the Naseptin seemed to be controlling nasal carriage to a large extent. Thus in Table XXVII, 346 (82.3%) of 420 treated patients either had Staph. aureus eradicated from the nose or were prevented from acquiring it. Only 49 (11.6%) acquired a staphylococcus in the ward. For the controls the corresponding figures are 223 (53.9%) and 120 (29.0%) of 413. Moreover, among the controls the incidence of sepsis was much lower in the non carriers and those who cleared spontaneously, 4 (1.7%) of 223, than it was in the patients who acquired staphylococci, 13 (10.3%) of 120. The same trend could be seen in the Naseptin-treated patients but it was striking that of the 260 patients who were persistently non carriers, 12 (4.6%) developed sepsis, compared with 2 (1.05%) of the persistent non carriers in the control group. Though the Naseptin seemed to control nasal carriage, it did not reduce the sepsis rate to the extent that might have been expected.

The incidence of symptomless wound infection is also shown in Table XXVII. The treated patients had a slightly though not significantly lower rate than the controls but as with sepsis the carriers had a higher rate than the non carriers.

Of the 21 Naseptin-treated patients with wound sepsis four had staphylococci of the same type in nose and wound, three of them having acquired the strains in their noses after admission. Nine of the 19 control patients with sepsis had staphylococci of the same type in nose and wound, seven having acquired the strain in the wards. However, it should be noted that 18 of the 40 septic wounds were infected with staphylococci of type 52/80 and this strain also very commonly colonized the patients' noses.

PART V

Progress and Conclusions

In this, the concluding part of the study only one table is presented for scrutiny, that of the quarterly sepsis rate and with it are shown details of organisms isolated from the two categories of wounds, septic infected and clean infected.

TABLE XXVIII

Progress. Quarterly sepsis rate for septic infected and clean infected wounds. November, 1957 to October, 1960.

		1957	1958				1959*		1960			
		4	1	2	3	4	1	2	1	2	3	4
Total patients		106	286	324	116	297	323	336	266	301	158	125
Percentage septic infected		14.2	13.6	9.9	9.5	14.1	10.8	11.6	9.0	9.3	6.3	3.2
‡Percentage isolation of:-	S.aureus	80.0	92.3	71.9	54.5	78.6	82.9	69.2	70.8	57.1	70.0	25.0
	E.coli	13.3	5.1	18.7	36.4	14.3	14.2	28.2	20.8	32.1	30.5	25.0
	"Others"	6.6	2.6	9.4	9.1	7.1	2.9	2.5	8.3	10.7	-	50.0
Percentage clean infected		9.4	11.5	9.0	7.8	10.4	16.1	19.0	18.4	15.9	27.2	18.4
‡Percentage isolation of:-	S.aureus	70.0	66.7	41.3	56.6	54.8	42.3	56.3	65.3	45.8	34.9	52.2
	E.coli	10.0	24.2	44.8	44.4	35.4	34.6	28.1	20.4	43.8	51.2	43.5
	"Others"	40.0	12.1	13.8	-	6.4	23.1	15.6	14.3	10.4	14.0	4.3

*No records available for 3rd and 4th quarter of 1959.

‡The isolations of bacterial species are shown as percentages of septic infected or clean infected wounds.

The percentage of septic infected wounds shows a distinct fall in the last two quarters of 1960 but the opposite is seen in the case of clean infected wounds. In fact there is an increase in the figures for the latter during the whole of 1960. It is difficult to relate this to bacterial species, as in the last quarter for 1960 the number of septic infected wounds was too few to allow of a reasonable deduction being made, but in the entire year there is a suggestion that isolations of E.coli were on the increase and the same could perhaps be said of the presence of E.coli in clean infected wounds.

DISCUSSION

The sepsis rate

As regards the amount of sepsis, the rate of 12.7% (Table I) for operation wounds that ought to have been clean, corresponds fairly closely with rates of other investigations of post-operative sepsis. These fall into two groups, investigations of outbreaks and investigations of rates of sepsis over a period, i.e. surveys similar to the one studied here. Of the latter, that conducted by Shooter and his colleagues (1958) consisted of an eight month's survey in surgical wards, leaving out, as in this, operations where sepsis was likely to occur, i.e. genito-urinary, open fractures and so on. Of the 179 clean operations observed, a sepsis rate of 14.5% was recorded. Shooter however, noted waves of sepsis, staphylococcal in origin while in this survey there seemed to be a constant level maintained with only a slight fall towards the end. Harrison and Cruickshank (1952) recorded a sepsis rate of 13.0%. Their observations however, were made under rather different circumstances and the survey was of chest cases in a thoracic unit. The total number observed was considerably smaller, 69 in all, and consisted entirely of potentially clean cases.

Another survey similar in many ways to the one being studied was that carried out by Robertson, Colbeck and Sutherland in the Shaughnessy Hospital, Vancouver (1958). In it observations were made from October, 1955 to the end of February, 1958, but Robertson began his survey after adopting a most thorough and strict regime for the elimination of sepsis. Such reforms as I was able to have put into practice, e.g. disinfection of blankets, isolation of septic cases, introduction of Phisohex, were adopted at various points along the three year survey, so that the Robertson figure of 2.4% of serious infections (infections where pus was present) plus that of 6.9% of trivial infections, making a total of 9.3% in all, in 1917 wounds, resembles rather more the percentage in the last quarter of my survey than the percentage in the earlier part. As regards potentially unclean wounds in Robertson's survey, the number of abdomino-perineal operations was not large, only 1.0% of the total whereas I did not include any.

Another type of investigation was that of Cunliffe (1957) who summarised, by collecting data of operations on a special form, information concerning 965 operations in Kings College Hospital in 1956. The sepsis rate for all operations observed was 6.1%, considerably lower than for the present series. In a pilot series covering the $2\frac{1}{2}$ months prior to this, his sepsis rate was 12.0% and although this was double the figure over the longer period, he believed the true rate to be even less than 6.0%. Many records were missed owing to patients being discharged before first dressings. It is interesting to note that Cunliffe records Staph. aureus being present in 10.0% of the wounds with no clinical sepsis. The figures for the same class of wounds (clean, infected) from which Staph. aureus was isolated in this series, was rather less than 10.0%.

Jeffrey and Sklaroff (1958) carried out an interesting survey in Edinburgh where a record was kept of all operations in four different departments - orthopaedic, neuro-surgical and two of general surgery - over a period of three months in the winter of 1956. No bacterial examination was carried out, but two grades of infection were carefully noted. Other differences from the present series were that the sister made the records, although a surgeon checked these carefully, and all wounds were included, i.e. accident and potentially infected wounds. Under potentially infected wounds, however, Jeffrey and Sklaroff included cases of gastrectomy, a type of operation which I did not consider particularly susceptible to sepsis because of the nature of the operation. Nevertheless the overall incidence of wound infection of 673 clean wounds, made up of 7.7% moderately infected and 2.1% severely infected, a total of 9.8%, is comparable with the rate in the present series. A rate which approximated more closely still is obtained if the figures for orthopaedic and neuro-surgical in Jeffrey and Sklaroff's report are omitted and only those of general surgery compared. The rate now becomes 12.6% for moderate and 2.6% for serious, a total of approximately 15.2%. Resnekov (1959) investigated a rather special group of cases, valvotomies, and describing a series of 70 found a sepsis rate of 14.3%. He was not able to define the cause of the sepsis exactly but brought forward evidence to show that torn gloves and consequent infection of the operation areas by the surgeon was a possible cause, the gloves being specially liable to rupture when inserting the fingers into the valve orifice.

Other sepsis rates from surveys include that of Burnett et al. (1958). Here a planned investigation took place over a period of seven months in 1956-57, and the results of 273 operations studied. Operations excluded were haemorrhoidectomies and opening of abscesses, but abdominal operations with peritonitis were included and

the sepsis rate was 9.5%. Apart from other minor differences in organisation the survey was somewhat similar to mine. A survey which was characterised by several unusual features so that rates are hardly comparable, is that recorded by Browne et al. (1959) in Canada. In several thousands of herniorraphies a series of 518 was found to have a sepsis rate of 7.3%. This series consisted entirely of operations by one surgeon who was disseminating a particular pathogen and the sepsis ceased when appropriate measures were taken. Sepsis rates following work of the other surgeons in this particular group were negligible. Another survey that was somewhat different was that described by Koch et al. (1959) and which took place in the surgical service department of the Marquette University School of Medicine, North America. Here two surgical blocks were set aside and while one continued to use the usual routine, the other was subjected to a very strict regime to exclude sepsis. The sepsis rates in the two blocks did not differ greatly and the overall post operative wound infection rate was 4.0% out of a total of 1350 operations. This may at first sight seem low but it should be noted that unlike all the other surveys mentioned, only sepsis caused by Staph. aureus was recorded.

Finally there is the clinical study by Howe (1956), that of Clarke (1957) and that of Ralston and Cowling (1959). In Clarke's series where 382 wounds were studied, 13.6% of sepsis occurred but the percentage in that of Howe was considerably lower. Howe studied a large series of operations over the period 1952-55 and although a rate of approximately 4.0% was present when he began his investigations, it fell through the adoption of control methods, to just over 2.0% in 1955. Ralston and Cowling and Colborne studied 448 patients and excluded from the study colostomies and neurological operations. They divided all patients into "clean" (such as thyroidectomies) and potentially infected, operations where the gastro-intestinal tract was opened. Clinically, when sepsis arose two grades were recognised, one where only slight amounts of pus discharged and the other which included those where a lot of pus discharged or the wound gaped. Erythema was not taken into account. Of the clean wounds 21 (5.9%) of 357 were infected and of the potentially infected 15 (16.5%) of 91 wounds were infected, a total therefore, of 36 (8.0%) of 448. Unfortunately only a few bacteriological swabs were examined, but Staph. aureus was the predominating pathogen. This is a survey which resembles my own fairly closely. I did not include colostomies or urological cases and if only those of my cases which discharged pus are counted, then a sepsis rate of 9.2% would have been obtained.

Sepsis rates from well defined outbreaks are in rather a different category, but it is interesting to consider them briefly. Penniket (1958) described a sharp outbreak with a sepsis rate of as high as 28.2% in a study of 48 patients. The outbreak was concentrated into a period of 6-7 weeks in 1957 in a London Hospital and terminated when the source of infection, a theatre nurse, was removed. Staphylococci of the same phage type as found in the patients was isolated from her throat and it was found that she was contaminating the suture material. Similarly Shooter et al. (1957) described an outbreak, again in a London hospital with a sepsis rate of 28.9% in a series of 83 operations over a period of 8-9 weeks. Again the outbreak terminated abruptly when the source of infection, a surgeon, was cured of his own septic foci. Mitchell et al. (1959) described two outbreaks, one of 11.1% in 45 cases and another of 17.6% in 56 cases. These two outbreaks arose from infection introduced by a particular surgeon, first when he had a septic finger and later when he developed axillary boils.

One of the earliest outbreaks of this kind to be examined was that of Devenish and Miles (1949) in a London hospital where suppuration appeared regularly on the 4th and 5th day following operation in 25.9% of 54 cases studied. A surgeon was found to be a heavy carrier of pathogenic staphylococci and the wounds were being contaminated at operation through holes in his gloves or through his sleeves becoming wet. Whether surveys have been carried out over a longer or shorter period, or concerned themselves with large or small numbers of patients, the overall picture is at one with that of my own survey. It demonstrates forcibly the regrettably widespread nature of post operative sepsis.

Bacteriological findings

The bacteriological findings, (Table I), i.e. the isolations of pathogenic bacteria from septic discharges from the wounds, also correspond with the picture that has been presented in other investigations in one particular aspect, that of the predominance of Staph. aureus. Alone, it was present in 54.4% of wounds and with other pathogens in 23.4%, a total of 77.7%. In the report of the Public Health Laboratory Service, 1960, it was found alone in 45.0% of septic wounds and with others in 15.0%, a total of 60.0%. Cases of peritonitis and appendix abscess, however, were excluded from these figures and it is noticed that 22.4% and 10.7% of these two types of case yielded Staph. aureus. Cunliffe (1957)

in his survey at Kings College Hospital found a rate of infection in septic wounds of Staph. aureus of over 50.0%. He did not however, examine all wounds bacteriologically, being content with sampling between 50 and 75%. Robertson (1958) similarly found Staph. aureus to be the predominating organism in his 2½ year survey. It was present in well over one third of his seriously infected cases and in nearly four-fifths of his less serious. Among other figures of infection by Staph. aureus are those collected by Howe (1958). As regards isolation of Staph. aureus in post operative sepsis of "clean" wounds, for example, he quotes Sompolensky et al. in Israel in 1952-55 as having a rate of 37.0%. In the hospital at Massachusetts where Howe himself was visiting surgeon, he quoted the infection rate of Staph. aureus of seriously infected wounds as being practically linear from 1949-56, a figure as high as 88.0% being reached. He then gives a series describing the incidence of Staph. aureus in traumatic war wounds, and quotes Wannamaker (1950-52) in Korea, a rate of 17.0% in brain operations; Linberg et al. (1952-53) in Korea, 46.0% in winter and 17.0% in summer; Florey et al., European theatre of operations in 1944, 25.0% in compound fractures of the tibia. Other war time figures he quotes are those of Roy et al. in Italy from 1944 to 1955 where in wounds of "soft parts" rates of infection with Staph. aureus range from 21.0% in wounds examined after 24 hours, to 38.0% in those examined at 5 to 10 days, and 73.0% examined up to 20 days after operation. Other investigations in this country include that of Blowers, who, reporting an overall post operative sepsis rate of 10.9% from 1943-54, stated that almost every infected wound yielded Staph. aureus. Koch (1959) set out to study only hospital sepsis due to Staph. aureus and in a series of 1350 operations noted that 51 patients (4.0%) acquired infection in the post operative period attributable to this organism. Burnett (1958) in a survey of 273 operations with a sepsis rate of 9.5% found Staph. aureus present in approximately one third of the cases.

Tables II and III show details of the isolations of Staph. aureus, other organisms isolated with it and all the organisms grouped under "others" in the two hospitals. Considering the relationship between the findings for each of the two hospitals such differences as appear are minimal and this was to be expected. The hospitals are situated about 1½ miles apart and deal with the same type of patient. Both are acute hospitals and though the number of beds in hospital B is fewer, 200 compared with 270, the turnover of surgical work is a little higher than in hospital A. The design of theatre is different and the wards of hospital B are larger than in A and contain more beds. There is, however, an interchange of nursing staff and patients are sent from hospital A to convalescent beds in B. There are other differences, but these will be discussed later.

Septic wounds from which E.coli was isolated were 15.5% for E.coli on its own but it was associated with Staph. aureus on 16.9% occasions. It also appeared with other organisms such as Ps. pyocyanea or B.proteus, but these latter were very few. Published records of the incidence of coliform infections of wounds are very scanty but in the P.H.L.S. Report 1960, the total incidence of post operative sepsis associated with infection by coliform bacteria only was 17.0%. A further 13.0% had sepsis in which coliform organisms were associated with other pathogens principally Staph. aureus. These percentages correspond well with my own. Figures are also available (Shooter et al. 1958) from a study in a surgical ward in which there were many patients who had had rectal and abdomino-perineal operations. Four per cent of the 179 wounds observed developed sepsis associated with coliform organisms only. Burnett (1958) however, found a higher result, approximately 22.0% of septic infected yielding E.coli on culture. Similarly Ralston (1959) in his series of 448 patients found a fairly high infection rate with E.coli, but not all wounds however, were examined bacteriologically. Of those that were so examined, 68.3% were infected with Staph. aureus and 32.1% with E.coli. The isolations of E.coli from potentially clean wounds (elsewhere than gut) was 22.2% and from potentially infected, i.e. those including gastro-intestinal cases was 50.0%. Howe (1958) gives some interesting figures comparing gram negative isolations with those of Staph. aureus. From 1954-57 he studied 82 "serious" wound infections and lists the percentages of the Staph. aureus or gram negative isolations as follows: in pure cultures, Staph. aureus 45.0%, gram negative 9.0%; as the predominant in mixed cultures, Staph. aureus 72.0%, gram negative 18.0%; as a component of cultures, Staph. aureus 83.0%, gram negative 24.0%.

Isolation of pathogens from operation sites

As regards the operation sites themselves and the particular organisms isolated from them (Table VIII), I can find no reference in literature to this having been studied apart from that of Cunliffe (1957). In my series Staph. aureus was isolated with equal frequency from practically all sites but it was surprising I thought, to find E.coli being isolated alone, in operations on the breast, (radical mastectomies) and in operations to relieve varicose veins, (Trendelenburg). Possibly the reason for the infection of the site in the Trendelenburg operation lies, particularly in the female, in the closeness of the site to the genito-urinary region and this may explain the presence of E.coli. The infection of septic cases in Cunliffe's series with Staph. aureus appears, like mine, to be fairly evenly distributed, but there is no reference to gram negative distribution. In Cunliffe's report

it is interesting to see that he had only one septic case in 90 operations on the head, neck and upper limb. In my series there was only one case which developed sepsis in 71 thyroidectomies. I cannot find an explanation for the difference in the sepsis rates in the two hospitals for operations on veins or radical mastectomies (Table VII). For each type of operation the sepsis rate in hospital A was more than three times that of hospital B. So far as I was aware there was little or no difference in technique and the type of patient was similar in both hospitals.

Categories of sepsis

The categories into which degrees of sepsis were placed were the same as those chosen in the P.H.L.S. Report, i.e. the main category, in which were placed all wounds developing frank pus, and subsidiary categories, describing minor degrees of infection, i.e. "stitch abscess", "serous discharge", "marginal erythema" and "healing by granulation". It was found subsequently that the majority of wounds fell into the main category and as well as discharging pus separation of the wound often took place. At the other end of the scale "marginal erythema" had the fewest cases. Most investigators who have carried out surveys have employed categories of this sort, usually dividing the groups into four, varying from minor degrees of erythema around a stitch, to frank infection of a large part of the wound with purulent discharge. In my series more than half the wounds were in this category, numbers being practically equal in both hospitals (Table V). In the investigation of Robertson (1958) a quarter of his cases were in this grade. Burnett et al. classified as infected all purulent wounds or wounds showing redness round the stitches and no further differentiation was attempted. Burnett's sepsis rate of 9.5% compares very well with a rate of 9.8% which would be obtained if only those cases in my series are counted which showed pus and "marginal erythema".

Symptomless infection

It is interesting to consider at this stage "symptomless" infection, i.e. the number of clean healed wounds from which pathogens were isolated (Table I). It was found during routine swabbing of wounds that those which had healed quickly usually yielded non coagulase producing staphylococci but from a certain number, 228, (12.7% of all wounds, Table I), pathogenic bacteria were isolated. The pattern of isolations from these clean healed wounds followed roughly the pattern of isolations from septic

infected wounds, i.e. the isolations were approximately the same in both hospitals and isolations of Staph. aureus exceeded all others. The total infections with Staph. aureus however, was less in clean healed than in septic wounds and that of E.coli was greater. An interesting feature also was that whereas Strep. pyogenes was found infecting on its own, only one septic wound, it was isolated on no less than 26 occasions (1.5% of all wounds) from clean infected wounds. It is more than likely that symptomless infection represents contamination from the environment or autogenous infection from the skin. I did not form the impression that it was due to autogenous infection from the nose in either the case of Staph. aureus or E.coli. In the nasal trial discussed later a nasal swab was taken at the time of the wound swab and no co-relation between nose and wound was seen. In the investigation of Burnett et al. a culture was taken in 33 patients of the skin at a distance from the wound, but no relation between the skin and wound was found. It is of interest to note that Cunliffe also found 10.0% of clean wounds showing infection with Staph. aureus.

Of possibly greater interest was the fact that whereas in 17 cases of sepsis no pathogens were isolated, in 16 of these the only organism isolated was a non coagulase producing staphylococcus. In one or two instances I found that the antibiotic sensitivity pattern of these organisms resembled that of the hospital type of Staph. aureus, resistance to penicillin, tetracycline or chloramphenicol being encountered. In this respect it is interesting therefore to read of the experience of Resnekov (1959) who in his series of valvotomies reported several instances where a non-pathogenic staphylococcus was considered responsible for sepsis. Fleming and Seal (1955) also describing 9 cases of staphylococcal infection following cardiac surgery, drew attention to three of these where the staphylococcus was of the non-pathogenic, coagulase - negative variety.

Results of sepsis

An attempt was made to assess the results of the sepsis. Table IX gives the result in days spent in hospital over the "average" for that type of operation, by patients developing sepsis in their wounds. The "average" was in fact practically identical with that forecast by the surgeon when making his estimate on the special form at the time of operation. When wounds developed pus the average extra number of days was thirteen. Meleney (1935) attempted an assessment and found that patients with sepsis remained in hospital on the average twenty-three days longer than patients with clean healthy wounds. Clarke (1957) records an excess stay of eight days but Koch et al. (1959) recorded an excess of

24 days. In his special series of valvotomies Resnekov (1959) reported ten cases of staphylococcal endocarditis following mitral valvotomy whose stay in hospital averaged three months instead of the expected three weeks. Rubbo (1948) attempted to make a monetary assessment by estimating the cost of increased bed occupancy from the increased number of days spent in hospital by patients developing sepsis after radical mastectomies. If, he said, 5.0% of surgical patients had an increased stay of ten days on account of sepsis, there would be a loss to a 500 bedded hospital of 2,500 bed days. Estimating the cost of a bed per day to be £1 10s. 0d. he stated that in a town the size of Melbourne this could mean a wastage of £15,000 a year. In the P.H.L.S. Report 1960 the measurement of the cost of sepsis was estimated by applying the sepsis rate obtained in the report to the number of 1.5 million surgical operations performed annually in all hospitals in England and Wales. This would give an increased bed occupancy of approximately 1 million days a year or about 3.0% of the total bed occupancy. The monetary cost would be in the region of £3.3 million. In my series the extra number of days was thirteen in patients whose wounds developed pus, but I doubt if this simple statement of days gives a real picture of what the appearance of sepsis means to those patients. All of them became worried and unhappy about their condition. They were upset when they saw other patients leave the hospital with clean wounds and it was difficult to reassure them that their wounds would eventually heal. To the monetary cost that has been calculated may be added the wretchedness and frustration of many patients, perhaps with resulting weakness and disability from having contracted wound sepsis in hospital.

Deaths due to sepsis

Although 40 patients died during the study there was only one instance where death could be attributed directly to sepsis. Blowers et al. (1955) reported two deaths directly attributable to sepsis and Fleming and Seal (1955) recorded five deaths from staphylococcal infection after cardiac surgery. Geoffrey and Smith (1958) found that 4.0% of deaths were due to Staph. aureus infection and 14.0% of deaths were hastened by Staph. aureus infection. From this they calculated that in their investigation in the year 1956, 129 people died primarily or secondarily of infection due to Staph. aureus. Frisby (1957) recorded 12 deaths in the years 1954-55 where death was due to staphylococcal enteritis following surgical operations.

Various factors and sepsis

It is interesting to look at the analysis of operations (Table X) and the relation of various factors to sepsis. Three factors are pre-eminent, length of incision, drainage and age. Those wounds that had an incision longer than six inches became septic more often than those which were shorter than six inches, and the presence of a drain greatly increased the chances of the wound becoming septic. Likewise age seemed to matter a great deal; patients younger than 30 had only from one third to a half the amount of sepsis as people over 50. In hospital A sex seemed to matter, males suffering more sepsis than females, but otherwise, the figures for either hospital did not differ very much. I cannot find any reference in literature to an analysis of this kind having been made, apart from the P.H.L.S. Report 1960. Most of these results are of course, what one might expect. Operations in old people tend to be more serious, more extensive and require longer incisions. A longer time is spent in the theatre, more tissue is exposed, there is more trauma of tissue, more liability to haematomas or dead spaces and if drained an avenue is provided for infection to enter. Each of these increases the risk of infection. I cannot find a reason why males rather than females suffered more infection in hospital A. The fact of the consultants having a higher rate than registrars or house surgeons is understandable as the surgeons undertake most of the major surgery, but an additional factor was that of one of the surgeons being a regular hand carrier of Staph. aureus.

Nasal carriage of staphylococci

The other point of interest in this table is that in one hospital patients found to be nasal carriers of staphylococci had a sepsis rate twice that of the non carriers. In the other hospital the rate was about equal between the two. This is a feature which has aroused much interest and several studies have been made to investigate the relationship between nasal carriage of staphylococci and sepsis elsewhere in the body. Williams and Miles (1949) studying industrial wounds and using phage typing found that when sepsis occurred it was often due to staphylococci of the same phage type as those in the nose. Valentine and Hall Smith (1952) showed this to be the case also for superficial infections of the skin, recurrent furunculosis, and Roodyn (1954) also showed this to be the case when patients had recurring styes. Gould and Cruickshank (1954) investigating superficial staphylococcal infections such as boils, furuncles and styes in nurses and other hospital staff, found that the rate was higher than among patients in general

practice and co-related this fact with the much higher nasal carriage rate in hospital. In practice they found that at least 80.0% of staphylococcal infections were autogenous. Williams (1958) suggested that nasal carriers of Staph. aureus suffered surgical wound infection more often than non carriers and the same author in 1959 in a London Hospital showed that the post operative sepsis rate was three times higher in patients who were nasal carriers of staphylococci than in those who were not. Weinstein (1959) also showed the same trend in his study of 125 patients who underwent thoracic surgery.

The predominance of sepsis in nasal carriers of staphylococci in one hospital at least, seemed to me to substantiate what had been found by other investigators and in fact, led me on to conduct a trial of nasal disinfection to observe the effect of such disinfection on the sepsis rate. In the meantime it is worthwhile studying other features of nasal and skin carriage of staphylococci which emerge from this investigation.

Isolations of staphylococci from patients' noses on admission are given in Table XI. The figure of 25.6% appears low compared with other published figures. Miles et al. (1944) found a nasal carriage rate of 49.0% in ward pateints on admission. Williams et al. (1959) found a nasal carriage rate of 38.0% in a comparable group of patients admitted to the surgical wards of a London hospital. Gould and McKillop (1954) found a carrier rate of 46.0% among adults in a city practice and 33.0% in medical students before hospital practice. Edmonds et al. (1955) however, found a lower rate amongst maternity patients on admission to hospital and Loh and Street (1957), a nasal carriage rate of 20.0% amongst entrants to a community hospital. A possible reason for the low percentage in my series was that swabs were for the most part taken within 24 hours and often within 12 hours or less of admission. It will be recalled, Methods page , that swabs were broken off into 6% NaCl broth and this enrichment culture was designed to pick up minimal inocula. Perhaps the fact that the town where these investigations were carried out is small and in a rural area has some bearing on this point. The rates quoted above are for London and Edinburgh.

The distribution of nasal phage types on admission was fairly similar in both hospitals and it is interesting to note the large number of different types found, 122 in hospital A and 117 in hospital B. The majority of strains were of Group I. If we now compare Table XI with XII it will be seen that the distribution of phage types in wounds differs considerably from that in noses on admission. Thus, although Group I strains still predominate in both tables, three strains, 80; 52/80; 52/52A/80, dominate the scene in Table XII, Group II strains having almost disappeared and

Group III strains appearing only to any extent in hospital A. These three strains for this combined hospital at least could well be described as "hospital type" staphylococci and later on it will be seen that these were "hospital type" in the real sense of the word as they were found contaminating blankets, mattresses, and the air in wards and operating theatres to an alarming degree.

Although therefore it is clear that the strain of Staph. aureus present in the nose on admission cannot be held responsible for the wound sepsis it is interesting to see (Table XV) that as patients remained in hospital so the flora in the nose changed. The phage types infecting the wounds also colonized the nose and Group I strains, particularly 80; 52/80; 52/52A/80, increased in greater proportion than any others. This is reflected in Table XIII where it can be seen that in hospital A, of 210 nasal carriers, 40 had sepsis and of these almost half had the same strain in the nose and wound. This therefore seemed to substantiate the findings of the various investigators quoted on page who had established a connection between nasal carriage of staphylococci and skin infection, sepsis in accidental wounds, and surgical wound sepsis. The proviso has to be made of course that in general it appeared to be certain strains of Staph. aureus that were responsible. There were however, noatable exceptions - strains 187, 29 and 3C.

Skin carriage of staphylococci

Before discussing strains further it would be appropriate to give here the findings on skin swabbing as this was done at the same time as the admission nose swab. A swab moistened in broth was rubbed over the skin at the probable site of operation and cultured by plating and enrichment. The results are in Table XIV. Not all patients were swabbed, in fact this was only carried out on a series of 538 patients. On the whole skin isolations bore a close relation to nasal isolations and staphylococci from the skin were often similar in phage type to the nasal strains from the same patient. These skin strains however, like the nasal admission strains were not usually the strains found later in the wounds. In fact out of 256 patients in hospital A who had skin swabs taken, only three subsequently had a nose, skin and wound strain the same. Thus neither the skin nor nasal admission strains were important causes of subsequent wound infection. An interesting finding by other investigators is that of Bassett et al. (Hospital Infection. Lloyd Luke Books) who in a series of 652 operations in which there were 31 cases of sepsis found that in just under half the nose, skin and wound strains were of the same phage type.

But there was little support for the idea of self infection, as sepsis was greater among non carriers than carriers. In another hospital the same authors describe 63 cases of sepsis and in only five were the nose and wound strains the same.

In yet another investigation however, an entirely different situation was described and Colbeck (1958) stated that infection was five times higher in skin carriers of Staph. aureus than in those who were not. He does not, however, state whether the phage types were the same in the skin and in the wound, and without this information the statement would appear to be valueless. When dealing with circumstances other than surgical wound infection the interpretation that I have placed on the relationship between nasal and skin carriage of staphylococci and subsequent infection need not necessarily apply. Earlier workers who studied nasal and skin carriage, e.g. Miles et al. (1944), Williams (1946) found that staphylococci could be isolated frequently from various sites, e.g. the wrist and although this often meant simple transfer from the nose it was clear that actual multiplication of staphylococci could occur on the skin. The importance of this was shown by Hare and Ridley (1958) and Ridley (1959) in more recent investigations which established the extent of perineal carriage. Just as the noses of patients become colonised by hospital type staphylococci, the noses, skin and perineums of hospital staff become colonised with these strains. It is therefore not the nasal or skin colonisation by house or street strains, but the replacement of these by the hospital types that appeared to be important. How important this replacement was and how large a part it played in wound sepsis remained to be seen.

The "hospital strains" for this combined hospital were mostly 80; 52/80 and 52/52A/80. Type 80 appears first to have been recorded in Australia in 1953 (Rountree and Freeman 1955) and since then has been found in many countries of the world. In America it is known as 80/81 or 52/42B/42C/44A/80/81 and it was recognised in this country early in 1954. According to Williams (1960) many epidemics are due to staphylococci of phage Group III, especially types 47/53/75/77; 75/77 and recently 83A. Group I type 52/52A/80 is common. Its variant 52/80 such as described here is also common. There was nothing remarkable therefore about the phage types of the staphylococci infecting the wounds in this series.

Skin antiseptics

The situation then in the study is that there appeared to be a relation between nasal colonisation by "hospital" staphylococci and wound sepsis but one was not quite certain how this relationship operated. In the meantime as the study developed problems were arising which had to be dealt with and which added to the investigations undertaken. The first was that the surgeons whose cases were being investigated were all interested in the antiseptics used as preoperative measures and wished to know if the one they were using was the one most likely to reduce sepsis. The results of the various operations in relation to the skin antiseptic used are given in Tables XVI, XVII and XVIII and the results following on the introduction of iodine in regular sessions is in Table XIX. When considering the results associated with these skin antiseptics there are certain points to be borne in mind. There was considerable variation for instance in the conditions affecting the work of the four surgeons.

Two of them worked principally in the theatre of one hospital, the other two did most of their work in the other hospital. At least that was the accepted routine for list cases, although there was some interchange for emergencies. The theatres were different in design and surroundings and subjected to different degrees of air pollution. Although all four surgeons regularly carried out major operations, the frequency of such operations, especially the heavier type of abdominal operations which usually carry a high incidence of infection, varied. One surgeon for instance had a preference for orthopaedic work, and many of his operation wounds had no drain inserted and the wounds remained covered up until the time for removal of the stitches. There was naturally less of the abdominal type of surgery in his lists. Another had a preference for genito-urinary work, yet frequently operated on difficult thoracic cases. Yet another had a high total of gastrectomies or gall bladder operations and also had rather more thyroidectomies than the average.

As regards the skin preparations used there was also variance so that one felt the only way to make a valid comparison was for all surgeons to use one antiseptic in regular sessions and then compare the results obtained with those following the antiseptic to which they had been accustomed. The antiseptic chosen was iodine and there were several good reasons for the choice. Gardner and Seddon (1946) Gardner (1948) Story (1952) Colebrook (1941) all found that iodine 2% in 70% alcohol, iodine 1% in 70% alcohol or iodine 2% in water 2% pot. iodide were superior to other antiseptics in sterilising the skin after suspensions of pathogenic

organisms were applied. Harrison and Cruickshank (1952) after experiencing a 10-15% sepsis rate in thoracic surgery over a three year period achieved a dramatic fall to 3.7% after changing from 1 in 1000 acriflavine in spirit to 1% iodine in 70% Ethyl alcohol. Gardner was of the opinion that although the alcohol itself was a good steriliser it was the iodine content of the application that was responsible for the permanency of the sterilisation.

As it happened I found that the introduction of iodine had little or no effect on the sepsis rate and I do not think this is surprising. It is practically impossible to sterilise the skin and although the application of a good antiseptic will reduce the number of organisms on the surface so that a swab will not produce growth, organisms in the deeper layers will survive and may be carried by incision into the deeper layers. Not that one would recommend that the use of a skin antiseptic be abandoned. I think it essential that as many organisms as possible be removed from the surface before the actual operation begins. But it seems that any good skin antiseptic will do this. In this respect the experiment of Burnett et al. (1958) is interesting. In 33 patients a culture taken of the skin at a distance from the wound yielded a growth of organisms in 32 cases. Culture of the wound was sterile in 18 of these. In eight of these the cultures were taken on the sixth day after operation. The investigators felt therefore that the use of chlorhexidine was satisfactory as a disinfectant of the skin. Nevertheless this investigation showed that of all the avenues through which a wound may be infected that of the skin was not of prime importance.

Glove contamination

The situation regarding gloves and possible contamination of wounds through puncture holes by staphylococci from the surgeons' hands was, one felt, a more fruitful one. A good deal of work on this has been done. There is primarily the classical investigation of Devenish and Miles (1939) which drew attention to a series of cases of post operative sepsis resulting from staphylococci gaining access to the wounds through holes in the surgeons gloves, from his arms through the sleeves of his gown when they became wet, and to a lesser extent through his mask. Harrison and Cruickshank (1952) were satisfied that dipping the terminal phalanges in iodine before donning the gloves was an excellent method of reducing the infection of glove interiors. Webster (1958) found that the incidence of glove punctures in 1000 gloves

was as high as 30.0% and showed that organisms readily passed from the operators' skin to the exterior of the glove especially if the gloves were wet. More recently Smylie et al. (1959) showed that the use of Phisohex was followed by a highly significant fall in the number of colonies of skin organisms grown from the finger pads of a surgical team at the end of operations.

It is presumed that the usual preoperative surgical scrub of a surgeon's hands and forearms removes many organisms from the skin but cannot remove those lying in its deeper layers. Sweating carries these to the surface so that they lie in the warm moist space between the skin and the glove. Here they may multiply rapidly and be released into the patient's tissues through holes in the gloves. Unfortunately the majority of punctures remain undetected until the end of the operation although a surgeon will change his glove at once if he knowingly cuts it. As 30.0% of all gloves are found to be punctured at the end of operations it is reasonable to suppose that this is a common source of sepsis. It is also probable that some infection regularly occurs through passage of organisms through wet sleeves. It is quite easy to show by placing a piece of wet gown material over a culture and touching the finger tips lightly onto it, that organisms from the culture will be transferred on the finger tips to another plate and it is reasonable therefore to assume that infection also occurs in this way. As to the number of organisms required to be left in the wound before infection will occur this is difficult to estimate. Howe (1958) quotes Wise as having studied 54 clean wounds prior to closure by means of a 5 ml. saline rinse and found staphylococci present in 59.0% of them with a mean colony count of 655 colonies per ml. Seventeen per cent of the strains were coagulase positive. Only two however of the wounds (4.0%) became clinically infected, both with staphylococci.

The results of Table XX bear out the possibility of infection as a result of glove puncture, as staphylococci of the phage types causing wound infection were isolated on 10.0% of occasions. In the study 14 persons engaged in operations, not necessarily performing the actual operation itself but handling instruments or taking part in such a way that infection could pass from hands to wounds, were examined over a period of 10 months. Judging by the frequency of isolation of Staph. aureus two were a distinct danger, two might be relatively harmless and the remainder were somewhere between the two extremes.

It would be beneficial therefore for a surgeon to have a study made of the flora carried on his hands after operations lasting for an hour or more and for those who produce Staph. aureus regularly and abundantly there is a remedy in applications such as Phisohex.

This is a procedure that instinctively one feels should be beneficial but it is interesting to note that the two heavy carriers worked together in one theatre and the two lightest carriers in the other and the sepsis figures were practically the same in both hospitals. On the other hand the fact cannot be disregarded that the strains of Staph. aureus isolated from the hands of one of the heavy carriers were identical with the strains appearing in infected wounds. Some other interesting facts emerge from this study. Mr. B. did not appear to carry Staph. aureus on his hands in even small numbers; in fact even micrococci only rarely appeared and his hands were sterile on 67 (79.7%) occasions after operations lasting an hour or more. Mr. C. on the other hand, was not so fortunate and could finish his operations with sterile hands on only 13 (25.0%) occasions. Micrococci were isolated frequently, 32 (61.5%) but Staph. aureus turned up on at least 7 (13.4%) occasions.

Considering Mr. A. we find that his hands yielded staphylococci frequently. He could only finish with sterile hands on 1 (3.7%) occasion, non-pathogenic staphylococci appeared on 12 (44.4%) and Staph. aureus on 14 (51.8%) occasions. The assistants, between them did not yield Staph. aureus often, only 8 (4.2%) isolations being recorded but of the two theatre sisters investigated, one yielded Staph. aureus frequently, 7 (35.0%), the other not at all. From this investigation therefore it would appear that some surgeons, assistants, sisters or nurses are in the fortunate position of not carrying Staph. aureus on their hands, at least in sufficient numbers to be picked up on swabbing, but others may carry Staph. aureus in sufficient numbers to be a possible source of danger. Mr. B. for instance only produced Staph. aureus on one occasion out of 84 swabs. Assistant W. similarly produced Staph. aureus only once but Mr. A. and Sister O. appeared to be regular and abundant carriers of Staph. aureus. The phage types produced by these two were as follows:

Mr. A	80 + (52/52A)	3
	52/80 +	3
	52A	2
	52A/79	1
	80 +	1
Sister O	7/42Ew	4

The next factor to be studied was contamination of blankets and the effect on the sepsis rate, and this was first taken up in February, 1959 when sweep plates using the method originally described by R. E. O. Williams, were made of the top blankets of all

beds in 11 wards of the two hospitals, surgical, orthopaedic, surgical-convalescent and medical wards for comparison. Some mattresses were also examined. The first results, 20th February, 1959 to 23rd February, 1959 showed that the blankets of eight wards were heavily contaminated with the staphylococci being met with in wound sepsis and those of three wards moderately contaminated. What was surprising was that the two medical wards were among the heaviest contaminated, 17/23 and 23/24 blankets respectively yielded many Staph. aureus on the sweep plates. The subject of blanket contamination has been a very topical one during the past four years and much work has been done on the disinfection of blankets and on the substitution for wool of material that can be laundered easily. Blowers and his colleagues (1955) established the efficacy of quaternary ammonium compounds as disinfecting agents for woollen blankets and later showed how cotton or Terylene substitutes were an improvement on wool. Schwabacher et al. (1958) showed that when blankets were disinfected with quaternary compounds in a test ward the total bacterial count was reduced and cross-infection decreased, but that further improvement took place when cotton blankets were used. Caplan (1958) found that disinfection of blankets with formaldehyde was an economic and efficient method and moreover no shrinking or matting was observed in a period lasting over one year.

Hitherto in neither hospital had any special treatment been given to blankets; either they had been washed in the hospital laundry or sent out to a commercial laundry, but a start was made in hospital A with the Lissapol Cirrasol process described by Blowers and Wallace (1955) and fortunately a local commercial laundry had already begun to use Arquad for disinfecting blankets. Those of hospital B were sent to this laundry. Check tests of both methods were done and satisfactory results obtained. It was not possible to have blankets disinfected more often than at discharge of a patient or every three weeks in a long-stay case, but every new admission was at least provided with clean and treated blankets. Following favourable reference to cotton substitutes it was agreed that replacements in future would be provided by purchases of cotton blankets. A second survey was carried out three months later on the same lines as the first, and judging the situation solely by the numbers of blankets yielding Staph. aureus, the position was worse in two wards, the same in one and in eight some improvement had taken place. In many wards, however, a complete change of strain of Staph. aureus had taken place. Five months later a third survey was carried out and results were disappointing. Some wards which had shown improvement at the second survey had deteriorated. In fact a widespread contamination with phage type 80 was found to be present. Moreover changes in the ward phage type had taken place. For the last survey the mean number

of colonies per blanket was estimated by dividing the total number of colonies of Staph. aureus on all plates of one ward by the number of blankets. Using this mean a rough estimate could be made of the amount of contamination in a ward and comparison was then possible between wards.

During the blanket checks it was noticed that the length of time the blanket had been on the bed bore little or no relation to the cleanliness. Staph. aureus was found in as little as 24 hours after putting clean blankets on a bed and this finding appears to be in keeping with observations of other investigators. Of the efficacy of the disinfection there was no doubt. Many blankets were examined after returning from either the hospital or commercial laundry and were always found to be adequately treated, sweep plates yielding no growth, but there was equally no doubt that the interval between treatment was either too long or the source of contamination in the wards too great.

Although no improvement in the sepsis rate resulted from disinfection of the blankets it is not considered that the procedure is valueless. It is true that Staph. aureus appeared on some blankets within 24 hours, but the general impression gained was that the amount of contamination, or total number of staphylococci, was rather less than before the beginning of the disinfecting procedures. The mean count was of some help in arriving at this conclusion and will be used in future surveys to estimate progress. In a way the complete change of strains in a ward also helped to form the impression of a lessening of the colonisation, at least it pointed to the removal of large depots of other strains; and although disinfection does not prevent rapid colonisation by a new strain, it may at least prevent a gradual build up of many strains. It was noticed, that on occasions contamination of a blanket was represented by a single colony. It is reasonable to assume therefore that regular disinfection of blankets should have some beneficial effect. (Gillespie et al. 1958, 1959).

Mattresses and pillows

The same remarks could apply to mattresses and pillows. Very little work has been done on mattresses but Colbeck (1958) investigating infection of mattresses in a two bed room showed that when non carriers used the beds the counts in the mattresses were low but when carriers occupied the room the mattress count rose considerably. In this survey a large percentage of the mattresses were

found to be infected with the phage types found in septic wounds. Mattresses cannot be disinfected as easily as blankets but it was possible to convert a room into a formaldehyde chamber. The mattresses were placed on their sides in wooden racks and by warming the air with steam and leaving formaldehyde vapour in the room overnight it was possible to disinfect them completely. Now this is being supplemented by the use of plastic covers and experiment shows that simply cleansing of the cover may eventually replace the need for formalinising.

Airborne infection in theatres

The final factor to be investigated was that of air pollution in the theatres and wards and the figures obtained on sampling showed heavy contamination by organisms, counts in the theatres being on the average, 20-30 per cu. ft. in one and 12-30 in the other. The ward counts were slightly lower, in one ward approximately 10 per cu. ft. and in the other 15-20. In all cases a proportion of these were Staph. aureus of the phage types being found in wounds (Tables XXIII and XXIV). The counts were made using a slit sampler. Airborne infection is a subject that has received much attention since the original researches of Wells (1934) and the slit sampler technique has been used in investigations of outbreaks of sepsis to measure the extent of air contamination and in research projects to study the direction of air flow in theatre ventilation. In the original studies by Bourdillon and Colebrook 1946, Bourdillon et al. 1948, the air studied in ward dressing rooms and operating theatres was found to have on the average 70 particles per cubic foot, a proporation of which were Staph. aureus. Many of these organisms were derived from contaminated dressings, from infected burns, blankets and the clothes of surgical and nursing staff. Movements of the staff about the room increased the numbers of airborne organisms partly by raising contaminated particles that had settled on the floor and partly by liberating fresh ones. Wallace and Duguid (1948) found the same thing, namely that even slight movement, such as would be carried out by a surgeon arranging the drapes at operation, increased the output of organisms and that wearing an ordinary cotton surgical gown over clothing did not prevent this release. The counts in this series were made during a routine operating session, with no undue movement of personnel in the theatre. The results in the two theatres were similar and examination of the air flow showed that there was no constant flow in any one direction, the pressure being about equal between corridor and theatres and in fact there was every possibility that air was being sucked in from the neighbouring wards via the corridor.

Bourdillon and Colebrook's work showed that in unventilated or poorly ventilated dressing rooms there was insufficient air exchange to prevent accumulation of pathogenic bacteria and there was no doubt in my mind that this is what was going on in the two theatres being studied.

Other workers, Blowers et al. (1955) Shooter et al. (1956) have also shown that the air in general surgical operating theatres may be likewise contaminated and that Staph. aureus is often present and may be associated with wound sepsis from strains of the corresponding phage type. Slit sampler bacterial counts are often as high as 40-50 per cubic foot and Staph. aureus counts vary from 1:20 to 1:100 of this. Contamination such as this may be accompanied by sedimentation counts of 10 contaminated particles per square foot per minute during the operation. When the rate for general bacteria is 10 per square foot per minute, particles contaminated with Staph. aureus may be landing on a 20 square inch wound at a rate of up to 5 an hour and on the sterile table and equipment at about 300 an hour. (Williams, 1960).

These figures of course may not be important if some of the particles at least do not carry Staph. aureus. Lidwell (1959) has shown that most of these particles contain only a few cocci, possibly this is the reason why, with so many particles landing in the wound area or on the instrument tables, there is not much more sepsis. Whatever the answer there is no doubt that some investigators have found considerable improvement in sepsis rates when ventilation has been arranged so the particle fall is lessened. Shooter and his colleagues (1956) found that when a powerful input stream of pure air was directed across the operating table and a positive pressure obtained inside the theatre, the bacterial counts of the air in the room were greatly reduced and the post operative sepsis rate fell from 9.0% to 1.0%. Lowbury (1954) reviewing the results obtained by Bourdillon and Colebrook (1946) and his own when treating burns in a special dressing room, air conditioned, and with an air filter, was able to point to considerable improvement in the sepsis rate.

One strong pointer to the fact that infections were occuring in the theatres in this survey was the presence in the air of the theatres of the staphylococci that were being isolated from wounds, e.g. phage types 80; 52/80; 53; 29/52/52A/79/80/54 and 6/7/47/53/75.

Trial of nasal disinfection

Although the impression I had formed was that infections were taking place in the theatre I was still not convinced about the place of nasal colonisation with staphylococci in self infection. Many writers had emphasised the importance of this. Williams et al. (1959), Weinstein (1959), Colbeck et al. (1959) had shown that nasal carriers of staphylococci experience a higher post operative wound sepsis rate than others. As far as hospital A was concerned in this series, it certainly was the case and it seemed worthwhile therefore, as all the arrangements would be easy and coming so soon after the investigations into wound sepsis, to carry out a trial of nasal disinfection. The results showed that no obvious benefit resulted from the application of the disinfectant cream to the nose; the number of septic wounds in treated patients was practically identical with the number among controls despite the facts that the nasal carrier rate was reduced by the treatment and that carriers had higher sepsis rates than non carriers.

There are several possible explanations of this apparent anomaly. The simplest would seem to be that the reduction in the carrier state was only apparent. The follow-up swabs were taken between $1\frac{1}{2}$ to 2 hours after the last application of the cream and such tests as were made seemed to demonstrate absence of sufficient carry-over to affect the cultures but it might be that there was persistent colonisation of some other area than that swabbed. This could explain the unexpectedly high sepsis rate in the non carriers of the Naseptin group.

Alternatively the anomaly could be explained if the wound infection was not derived from the nose, and if both wound infection and nasal colonisation are ordinarily acquired from a common source. If so elimination of nasal carriage could not be expected to reduce the risk of sepsis, except in so far as it reduced the total number of sources of infection in the ward. In my wards the number of patients applying the disinfectant cream at a given time was less than half - allowing for the numbers using the control cream, fresh admissions not yet using either, and patients not included in the trial, such as those with urinary operations, colostomies, etc. - many of whom were certainly carrying staphylococci in their noses.

The rationale of nasal prophylaxis rests on observations such as those quoted earlier showing that nasal carriers experience a higher post operative wound sepsis rate than non carriers. There is also the great bulk of evidence built up over the last 15 or so years that nasal carriage of Staph. aureus

is responsible for much self infection of the skin and for styes, boils, carbuncles, etc., e.g. Gould and Cruickshank (1957). But as far as wound sepsis is concerned it has to be added that other studies have failed to show any great excess of sepsis in carriers (e.g. P.H.L.S. Report 1960 and extensive unpublished studies of Bassett et al. cited in Williams et al. 1960). In part the differences in experience probably derive from the differences in method. Thus in the P.H.L.S. survey a single nasal swab was taken at the time of admission, and the present study would also have shown no difference on this basis. In part the differences must also reflect differences in the place in which infection of the wound occurs: in the St. Bartholomew's Hospital study of Williams et al. (1959) ward infections were thought to be predominant. In other investigations (including perhaps the present one) theatre infection seems to have been more common. Possibly also the characteristics of the infecting staphylococci are important.

It is more difficult to assert that, even if carriers experience high wound sepsis rates, the wound infection is derived from the nose rather than that both are derived from a common source. Williams et al. (1959) found that nasal colonisation often preceded the wound sepsis but without very frequent swabbing the time relation cannot be determined with any great certainty. In a situation where most of the infections occur at the time of operation, it could well be that an association of sepsis with nasal carriage might often represent infection of the nose from the wound. In the present study both nose and wound colonisation were very commonly observed together at the first post-operative swabbing, even though the majority of the wound infections were due to staphylococci acquired in the hospital.

Attempts were made to control wound sepsis by nasal prophylaxis by Weinstein (1959) and by Gillespie et al. (1959). Weinstein was quite unsuccessful. Gillespie and his co-workers claimed some success but they did not distinguish clinical sepsis from symptomless infection and it may be significant that in my work there was a suggestion that symptomless infection, though not sepsis, might have been lower in the Naseptin group than in the controls. Gillespie et al. observed their greatest reduction in wound infection when many other precautions as well as nasal prophylaxis were used and, moreoever, they treated all the patients in the ward. It may be that the effect of the nasal treatment was less on the individual patient than on the ward as a whole.

It is pertinent to enquire why, in 49 cases the use of Naseptin was unable to prevent the patients acquiring a Staph. aureus in the nose. In some of these cases it appeared that

application of cream had been irregular. Some of the patients were elderly, often hard of hearing, and sometimes senile, and such patients could not be expected to remember to insert cream regularly let alone efficiently. A few patients, after operation, found themselves with a rubber tube in their nasal passage to assist in the emptying of the stomach; others had both arms immobilised by intravenous drip apparatus also making application of cream difficult. Some of the failures were thus accounted for but there is equally no doubt that in many cases the cream had been regularly and carefully applied, yet colonisation was not prevented. In a further 25 cases, Staph. aureus in the nose on admission, was not eradicated. This may not have been so important, as often the strain in the nose on admission was not one of the strains usually found in surgical wounds and at least it could be said that in these cases Naseptin prevented colonisation of the nose by a hospital strain. Nevertheless, prevention of colonisation of the nose by staphylococci by application of a nasal cream, or the eradication of a staphylococcus already present, is not as easy as is sometimes suggested in the literature.

Conclusion

As a conclusion to this study I would have liked to have been able to point to one measure guaranteed to reduce the post-operative sepsis rate but perhaps the answer lies not in one measure, but in a combination of many. Throughout the study a certain amount of information has been collected and evidence brought forward to show that of some measures that have been described in the literature, no one, if introduced singly, has any dramatic effect on the sepsis rate. On the other hand the sepsis rate fell in the last two quarters of the period under review, so that it is possible, in fact likely, that innovations introduced over the three years may at last be beginning to have a cumulative effect.

It is interesting to note one point however, namely that although isolations of Staph. aureus are less, those for E.coli and "others" show a suggestion of an increase, more particularly in the symptomless infection of clean wounds. I cannot tell the reason for this. No one measure adopted to reduce the sepsis rate was aimed particularly at the staphylococcus except the Naseptin, but this was given to less than half the patients on a ward at any particular time. I had the impression that isolations of E.coli from nose swabs were more frequent in the wards when Naseptin was being used and it was certainly reflected in the isolations from clean infected wounds.

It is important to attempt to define the source of wound infection as this would obviously help in deciding upon the measures best suited to control it. I came to the conclusion that wound infection was taking place in the theatres. This opinion was based on several facts and the first of these was that the majority of wounds appeared to have deep seated infection. Thus the wound would appear to be satisfactory for several days and then about the fifth day, or later, local disturbance would be visible in the wound and eventually pus would burst out, often with the wound breaking down and wide gaping taking place. If the wound required to be reopened then the deep seated nature of the central focus would be apparent. The second fact was that in the experiment concerned with the examination of the surgeons' gloves staphylococci of the phage type found later in septic wounds, were present on the palms, fingers and on the inside of the gloves of one of the senior surgeons, in fact, the surgeon who carried out the largest number of operations in the Group hospital. In addition to this similar staphylococci were found on the same sites on the hands and gloves of the theatre sister and some of the assistants. Thirdly the air in both theatres was contaminated to a high degree and again staphylococci of the same type as found later in the wounds, was isolated from the air of the theatres.

There is in addition some indirect evidence which convinced me that the majority of wound infections were taking place in theatre. The method of treating convalescent patients was different in both hospitals. In one hospital a large number of wounds were occluded by adhesive dressings such as elastoplast and were not looked at, unless sepsis occurred, until the day for removing the stitches. In the other hospital many of the wounds were covered by a manytailed bandage which often slipped. Thus one set of wounds were occluded from the air and the other set were open to infection. The sepsis rate, however, remained practically the same in both hospitals. If ward infection of wounds had been taking place I should have expected the sepsis rate to have been considerably higher in the hospital where the wounds were exposed.

Another fact was that in December, 1958 a Group A haemolytic streptococcus was introduced into one of the wards under study in hospital B. This streptococcus was subsequently dispersed throughout the other surgical ward and eventually found its way to hospital A, appearing in the surgical wards there before the end of the second quarter of 1959. During this period it was isolated from nose and throat swabs, skin swabs and from the surfaces of clean infected wounds but not once during this period from septic infected wounds. The organism was a Group A Lancefield strain and if there is anything in ward infection of wounds, I would have

expected some wounds at least to have become infected with it and to have shown clinical sepsis.

Again, the amount of symptomless infection, i.e. the fact of isolating pathogens such as Staph. aureus, of one or other of the phage types 80; 52/80; 52/52A/80, or E.coli, from the surface of clean wounds helped to strengthen this impression. These wounds looked perfectly healthy, healed in the appropriate number of days, yet these pathogens were present. Observing that these pathogens had no effect on the wounds led me to conclude that if the edges of a wound were neatly approximated then pathogens in the ward environment would play no part in causing wound infection. Wounds that were drained were in a different category and in these cases there was no doubt that pathogens from the ward environment were causing infection. They were isolated from the discharge from the drains but I did notice that the infection confined itself to the outlet of the drain and there was no case when the wound proper appeared to have been infected via the drainage opening.

A further point which I feel helped was the absence of any effect of blanket disinfection on the sepsis rate. There is no doubt that a blanket when disinfected became re-contaminated in from 24 hours to a week when returned to the ward environment, but there seems equally no doubt that regular disinfection reduced the total load of staphylococci considerably. Instead of the sweep plate being literally covered by staphylococci, only one or two colonies appeared and I feel that through regular disinfection the number of staphylococci per cubic foot of ward air was reduced. Had ward infection been the more important I should have expected to see at least some reduction in the sepsis rate.

As I am convinced that infections were arising in the theatres, it is of interest to be able to record that the post-operative sepsis rate in hospital A at the time of writing is low, not more than 1.0%, possibly even less judging by the records kept in the wound sepsis register in the surgical wards. I put this down to repairs having been carried out in the ventilation system of the theatre and as a result there are now 10-12 changes of air per hour and a perceptible positive pressure. Rigid precautions have also been introduced to guard against the possibility of the introduction of organisms into the theatre and in addition the surgeons use Phisohex for preoperative cleansing of the hands. Many other reforms have been introduced, disinfection of blankets as already mentioned, septic dressings are carefully disposed of into plastic bags, cases of sepsis are isolated whenever they occur and staff are promptly removed from duty when septic lesions appear. All this has helped to reduce the load of staphylococci in the hospital and the risk has been lessened of these staphylococci being carried to the theatre.

To turn for a moment to nasal carriage of staphylococci; if nasal colonisation plays a part in wound sepsis by causing self infection then mechanical removal of staphylococci from the nose would surely reduce the sepsis rate. It is possible that a nasal disinfectant cream may prevent a patient's wound being infected with a staphylococcus from his own nose, but it is no guarantee against his wound being infected from someone else's nose or wound. On the other hand if the nose of everyone in the ward, including the noses of the staff, are treated with a disinfectant cream, then infection could be expected to be very much less. Certainly this has been done (Gould and Allan, 1954) with a subsequent reduction in general cross infection by Staph. aureus and moreover this reduction prevailed as long as the carrier rate remained low. There is a case therefore for general use of nasal prophylaxis as a means of suppressing the breeding and multiplication, and subsequent dissemination of dangerous staphylococci in order to prevent indirect contamination of wounds. I mean by this suppression of organisms which would eventually have found their way to the theatre, but this is a heroic measure which is perhaps not necessary in normal times, although it might be useful in an epidemic. Thus I support Elek (1960) who regards the nose as the breeding ground of staphylococci in hospital wards, thus producing a pool from which every department will eventually be contaminated, the most important of these being the operating theatre. In this connection the information gleaned from Table XV is important as it shows that if any measures are to be adopted to prevent colonisation of the nose by hospital type staphylococci they must be put into effect immediately after the patient is admitted to the hospital ward.

RECOMMENDATIONS

As a result of the work done in this study and the experience gained I would like to make the following recommendations for reducing the post operative wound sepsis rate in any hospital.

It is essential of course to have a correct estimate of the sepsis rate. My experience has been that it is unwise to depend for this on the opinion of the surgeon, his assistant or the ward sister. A sepsis register must be maintained either in the ward or operating theatre and every case of sepsis must be recorded. The register must be examined frequently or entries will be omitted through forgetfulness, haste, change of staff and other reasons.

Isolation of septic cases

When it is decided to undertake active measures the most important in my opinion, is the isolation of septic cases. It is obvious that no other measures are going to be of any avail while septic cases are allowed to remain in surgical wards. It is useless to disinfect blankets, dispose of surgical dressings into bags, wet-mop floors, use Phisohex on the hands, insist on careful theatre techniques, when the depots of sepsis themselves are allowed to remain in wards re-infecting noses, bedding and environment. This is a problem which must be tackled vigorously and to illustrate some of the difficulties that might arise let me say that in my own area, near hospital B, there is an isolation hospital to which it was hoped septic cases would be removed as soon as sepsis became evident.

Although surgeons were eager to transfer convalescent cases which did not require much in the way of treatment, they refused point blank to consider moving any patient who was ill or required special care. Nor could they be blamed for this as there was no resident house officer attached to the isolation hospital nor could the standard of attention in the ward be expected to reach that of a surgical ward of an acute hospital. There were also other reasons why some septic patients could not be removed to the isolation hospital. Some of the worst who discharged pus over long periods and who acquired septic bed sores, were elderly orthopaedic patients on extension who simply could not be moved because of the apparatus surrounding them.

For these reasons therefore and others the isolation hospital, although it was quite near and had good cubicle accommodation did not prove a solution to the problem. For much the same sort of reasons I doubt whether a septic block within a hospital can be regarded as any more acceptable unless it is on the same floor as the surgical or orthopaedic block and there is free access. Under these conditions ventilation will have to be very carefully arranged in order to prevent air currents carrying the organisms of sepsis back to the wards. There are other objections to the septic block. Concentration of sepsis in one locality even with the best ventilation may lead to a collection of resistant strains in that locality and even if cross infection does not take place among the patients then the nursing staff of the block will be subjected to heavy attack from these organisms. It is reasonable to assume that the block will be staffed separately but there will be little to prevent the nurses dispersing such organisms in the nurses' home, dining room and elsewhere, even assuming they are most careful about the use of gowns and masks. These nurses will most likely become skin, nose and perineal carriers.

In my opinion the best solution for the isolation of septic patients is the provision of an adequate number of cubicles in every surgical and orthopaedic ward. Air would be extracted from the cubicles by an extractor fan and discharged outside the buildings. These cubicles could be cleaned and disinfected easily after housing a septic case and in periods of quiet with no sepsis, could be used for other patients who might benefit from being on their own. Organisms of sepsis would not collect in one locality and nurses would not be exposed to a heavily infected environment.

Theatre. Positive pressure of air

As regards my own hospital group I hope I have shown that theatre infections predominated and it is natural therefore that I should place recommendations in regard to the theatre before those connected with the ward. I consider it essential to have a ventilation system in the operating theatre which will ensure that filtered air enters at a rate sufficient to bring about a positive pressure. This is not the place to discuss the technical details of such an installation but, as I have said earlier, it was possible by carrying out simple modifications to an already existing fan in the ventilation system of one theatre in the group, to effect an air change rate of 10-12 per hour. Without instruments it was possible to be aware of the positive pressure so caused by simply placing one's hand over the opening

between the swing doors when a perceptible draught was felt. Smoke tests and the use of an air velocity machine confirmed the presence of a positive pressure. A positive pressure of air in a theatre acts by blowing organisms out of the theatre and it further acts as a barrier to organisms being carried along from the wards to the theatre on air currents. Other observers have confirmed the efficacy of this procedure, e.g. Shooter (1956), Blowers et al. (1955), Lowbury (1954). I myself, using a slit sampler since the alterations to the fan have confirmed that a considerable reduction in the contamination of the theatre air has taken place and I am convinced that the reduction in the sepsis rate in this particular hospital is in a large measure due to the introduction of a positive pressure in the theatre.

Use of Phisohex as a pre-operative hand cleanser

At the time of writing this preparation has been examined by other observers and does in fact bring about either a considerable reduction or complete removal of Staph. aureus from the hands under operating conditions. Following my own experience in theatre B where the senior surgeon and theatre sister were found to be heavy hand carriers of Staph. aureus, extremely satisfactory results were obtained after the use of the Phisohex hand washing technique, and following the experience of others, e.g. Smylie et al. (1959), I have no hesitation in recommending the Phisohex hand washing technique in operating theatres. The Phisohex technique is simple to carry out and although one has heard of complaints of skin irritation following its use, I have never actually come across anyone in either hospital during the past two years who has experienced trouble following its use.

Reduction in the number of personnel in the theatre and elimination of unnecessary movement.

Personnel in the theatre should be reduced to the absolute minimum. There is a tendency for a place to be found in the theatre for an anaesthetic nurse, a nurse in training and so on. In my own case while carrying out the air sampling described on page the entry of a group of preliminary training school nurses to view their first operation was followed by a considerable increase in the bacterial content of the air. This sort of observation has been made time and again by other observers yet tutors, matrons and surgeons are unwilling to break with

tradition. Reform should also be brought about by reducing the amount of movement in theatres. Duguid and Wallace (1944) originally showed that simple movements such as arranging a sheet or towels, as in an operation, caused a rise in the number of particles in the theatre air, and it should be a sine qua non in a well conducted theatre that movements should whenever possible be smooth and unhurried.

Skin preparation

The experiments described in this study when iodine as a pre-operative skin preparation was introduced in regular sessions and the sepsis rate following its use compared with that following the skin disinfectants routinely used, has led me to believe that the selection of a pre-operative skin disinfectant as a means of preventing post operative sepsis is of secondary importance. I feel that any good proprietory skin disinfectant when used in the proper strength will give satisfactory results. Nevertheless it is interesting to study the result of Verdon (1961) who by using replica plating showed that the best skin preparation of eleven tested was 5% Laurolinium. As a result this preparation is now used as the standard pre-injection skin disinfectant in all hospitals of the Portsmouth group served by the Central Sterile Supply Depot of that area. As however, the majority of wounds in my series were infected by Staph. aureus some of the surgeons in my group have been experimenting with Phisohex as a pre-operative skin preparation. As it is too soon to judge the results I cannot fully recommend the use of this preparation.

Introduction of organisms of sepsis from wards

In this section I should like to consider contamination by organisms brought to the theatre on trolleys, contamination by blankets and coverings of the patient and contamination brought in by those attending the patient. The ideal would be for one set of personnel to bring the patient on a conveyance from the ward to some spot in the theatre suite and then for the patient to be transferred to a fresh conveyance by personnel suitably attired, who never leave the theatre precincts and who would then bring the patient to the table. This ideal is practically impossible in a provincial hospital due to shortage of the appropriate staff. How often does one see a theatre porter dispatched to the ward for an x-ray or some note that should have accompanied the patient and disappearing into the hospital in his theatre attire, reappearing presently without changing

his gown. It is difficult to teach personnel of this grade the fundamentals of sepsis control and the best that can be done is to insist that the patient at least be brought in a gown that has been freshly laundered, that he is covered by a newly disinfected blanket and that the conveyance be taken over at the entrance to the suite by the theatre staff. One measure I have found to be of practical use in this respect is to have a sheet of polyester foam, e.g. "Foamoprene", about ¾-1" thick and several feet wide placed across the corridor leading to the theatre entrance. It is kept soaked in a suitable disinfectant. The foam absorbs a large quantity of disinfectant and prevents organisms being carried into the theatre suite on the feet of attendants and trolley wheels. The sheet however should not be too large as it becomes unwieldy when being washed. Several smaller pieces placed together are managed more easily than one large piece.

Personal hygiene

Enough has been said elsewhere of gowning and masking, but following the researches of Hare and Ridley (1958) and Ridley (1959), I doubt if enough attention is being paid to the problem of dispersion of staphylococci from the skin of theatre personnel. Much attention is paid to making certain that the surgeon is adequately covered by the gown but often none at all to the gowning of the nursing staff or theatre auxillaries. The gowns of all personnel should be adequate to cover the body. As the importance of skin and perineal carriage of staphylococci has been amply demonstrated no member of the theatre staff should take part in an operating session without having had a bath. Showers are usually provided for the surgical staff, but often the needs of the nursing staff are over looked. It is presumed that resident nurses will have their bath in the nurses' home before coming on duty, but provision must also be made in the theatre suite for part time staff who form an ever increasing force in hospitals today. It goes without saying that no person who is a nasal carrier of staphylococci or who has a septic lesion, no matter how trivial, should take part in an operating session.

Wall and Floor Application

A demand may be encountered from the theatre staff for advice as to which application is most suitable for washing down the walls and floors of the operating theatre. In my experience Osyl proved satisfactory and claims have been made that it has a

residual action particularly against staphylococci which will persist for several days after its application. Recently however attention has been drawn to the Tego series of compounds by Frisby (1959) and supporting evidence as to the efficacy of their use has appeared e.g. Jones and Howells (1961). The Tego series of compounds, amino acids of high molecular weight are marketed as ampholytic surface acting bactericidal agents. The principal compound which I would recommend is Tego M.H.S. which is supplied in such a strength that when the container is attached to the tap it will give a 1.0% spray. This can be used as a floor, ceiling or wall wash which appears to give satisfactory results.

Operating technique

Throughout the study I was impressed by the amount of minor infection, i.e. scabbing and discharge, that followed imperfect approximation of the edges of the wound. This was particularly noticeable in sites such as the inguinal region (hernias) and especially following operations carried out by junior members of the staff. All surgeons should approximate the wound edges in every operation with the care and precision that they would in a thyroidectomy. A more difficult problem is that of drainage. Sepsis often followed drainage of the wound and in radical mastectomies in particular where there were on occasions, two drain openings, both became infected with staphylococci in a large number of cases. Although this infection of the drain openings did not necessarily result in general infection of the wound, nevertheless the out-pouring of pus and contamination of dressings represented a considerable source of infection in the ward with much dispersion of staphylococci into the ward air. It is realised of course that there are situations where a drain is essential, but at least one surgeon in the group has begun to experiment in this matter and uses drains only where they are absolutely necessary. Radical mastectomies are no longer drained and the resulting accumulation of serous fluid is removed by a syringe and needle. I hesitate to recommend this as a general procedure as it is too soon to judge results. More experiment is required.

Another operating technique which I would recommend as a means of lowering the post operative sepsis rate is the use of plastic seals. It was noticable throughout my study that minor degrees of sepsis in wounds which are associated with ward infection did not occur when the wound was treated with Nobecutane. This observation has been amply corroborated by Rountree et al. (1960) although this group of observers decided

that sepsis in surgical wounds arose principally in the wards. Figures in their series strongly support the use of plastic seals. Thus, of 171 sealed wounds 12 (7.0%) were infected, but in 4 of these the seals were defective and broke, and in 2 infection took place late in the post-operative period when the seal was probably no longer effective. This was an infinitely better result than that obtained in 27 unsealed wounds where gauze pads were applied and where the infection rate was 56.0%.

The final technique which I would recommend is that of spraying "Polybactrin" into each layer of the wound as it is closed, as described by Forbes (1961). Polybactrin is a spray containing neomycin, polymyxin B and bacitracin and although it has only recently been brought into use in my own group, early results seem promising. Although strains of Staph. aureus separately resistant to neomycin have been reported from America, Quie et al. (1961), I cannot find a record of a strain having been reported as resistant to both. Lowbury (1960) tested over 300 strains of Staph. aureus and could not demonstrate resistance to either of the two antibiotics. Other observers, e.g. Gibson (1958) and Gillespie et al. (1959) have reported good results following the use of Polybactrin. In a series of 6419 wounds over a period of 4 years Forbes could find no case of allergy or other side effect in the patients who had been sprayed or among staff who had been in daily contact with the spray. Forbes states that it might be assumed that so long as this triad of antibiotics is applied topically in high bactericidal concentration, resistant mutants are unlikely to emerge. I consider that this form of prophylactic spray would be especially useful where infections are arising in the theatre.

Wards. Dressing cubicle.

As the great majority of wound infections in the group originated in the theatre, ward infection in my opinion played a secondary role, nevertheless, the ward probably forms the depot where the majority of the organisms of sepsis originate and multiply. I have already advocated cubicles for the isolation of septic cases but if this is not possible one such room at least should be provided for use as a dressing station. It should have doors wide enough to admit a bed and should be large enough to contain the bed, the dressers and their equipment. There should be an extractor fan on the outside wall adequate for making sure that the air of the cubicle is drawn outside the building. When a wound is dressed the technique should be meticulously correct to ensure that the nurses' hands or clothing should not be contaminated. The dirty dressings should be placed into disposable bags.

General ward technique

If a dressing room is not available then nursing personnel changing dressings in an open ward should be doubly careful. In addition to routine techniques such as that of "no touch" I should like to recommend a method that has been found useful here in lessening the dispersal of organisms. The first is that the patient should have a disposable cap and mask and the nurse should put on a clean gown and disposable cap and mask for each dressing. Before removing the dressing the nurse puts on each hand a polythene bag measuring 10" x 5". Dirty outer dressings are carefully removed and placed in disposable paper bags and as she removes the dressing nearest the wound she places it and the polythene covers, which she allows to slip from her hands, into the bag.

Blankets

If woollen blankets are still in use they must be treated with one of the quaternary ammonium disinfectants, e.g. Lissapol-cirrasol, (Blowers and Wallace, 1955; Gillespie et al. 1958). Usually the most practical way to do this is for the blankets to be disinfected when a patient is discharged from hospital. It would place too much strain on a hospital laundry to do it oftener, but if the patient is likely to be a long time in hospital then blankets should be disinfected at intervals of two weeks or at the most three. Unfortunately this type of disinfection will not deal with Ps. pyocyanea and in the case of a genito-urinary ward or burns unit it will be better to change to cotton blankets entirely, which can be boiled. Alternatively the method suggested by Caplan (1959) of exposing blankets to formaldehyde vapour in a vacuum could be adopted. This is an efficiant and easy way of disinfecting blankets provided one has a steriliser available, and Ps. pyocyanea, B.proteus and Staph. aureus are quickly killed. Alternatively the blankets could be treated with synthetic phenolic compounds such as Hycolin (Larkin et al. 1961). Mattresses and pillows should be disinfected by formalin or ethylene oxide vapour at similar intervals and where this is impossible polythene or plastic covers should be brought into use. These can be sponged or wiped down with disinfectant. It is true that blankets become contaminated again within a few days, but frequent disinfection prevents an excessive build up of organisms in the blankets. This was particularly noticeable in my study.

Nasal disinfection

This has certain drawbacks. Application of a nasal disinfectant cream does not always prevent the nose from being colonised or eradicate a staphylococcus already present (Henderson and Williams, 1961) and it is doubtful if in ordinary circumstances this sort of prophylaxis is necessary. In an outbreak of post operative sepsis however, nasal disinfection of all patients and staff of a ward should certainly be carried out and in this respect the information provided by the experiments of Stratford et al. (1960) is of value. These observers have pointed out the risk of missing a proportion of nasal carriers by use of the vestibule swab and recommend the use of a swab placed more deeply, just below the middle turbinal. In their series a further 17.0% of carriers of nasal staphylococci were detected in this way. They further showed that an intra nasal Soframycin spray containing framycetin and gramicidin cleared the nose of staphylococci much more efficiently and more quickly than any other preparation. Elek and Fleming (1960) recommended the use of an aerial spray containing BRL. 1241 (Celbenin). They found this efficacious in clearing the noses of infants in a nursery unit of a London hospital and recommended the procedure as economic in labour and materials. More research, however, is required before this method of nasal prophylaxis can be recommended as a routine measure for adults.

General ward hygiene

The ideal way in my opinion to clean the floor of a surgical ward is flooding and wet pick-up as practised in the United States, but there are few floors in provincial hospitals which are suitable for this procedure. Often the only effective way possible is damp mopping and this can be very effective if the mops are kept clean and enough antiseptic detergent used to ensure effectiveness up to the end of the operation. The use of brooms should be banned and vacuum cleaners also unless they have had a suitable filter inserted. It has been shown that organisms can be dispersed widely throughout the ward by being blown out through the cloth of a vacuum cleaner (Bate and James, 1958). As regards curtains a measure which I can recommend through personal trial is the use of those made of fibre glass. Previously in the hospitals of this group cotton curtains were used and I have repeatedly found that bacterial counts from these curtains were high. Fibre glass curtains which can be washed down in situ were introduced some months ago and counts were found to be greatly reduced.

Minor recommendations which I would make are:

1. The use of Sterzac, a non-irritant hexachlorophene powder as a dusting powder, especially in older patients where there is a danger of the skin breaking down and bed sores forming. Sterzac as a dusting powder, has been found extremely useful in maternity units as a means of controlling the spread of staphylococci among infants, and it has been used extensively in this group as a means of limiting the number of staphylococci on the skin of old people and in orthopaedic cases.

2. The use of either a hypochlorite solution and detergent or a solution of hexachlorophene for cleaning baths. Staphylococci can be transferred from one patient to another through a contaminated bath, and the application of either of these two solutions will limit this danger.

3. Strict attention should be paid to crockery and for this all that is required is for the water to be hot enough.

4. Barber's brushes and other instruments should be made the subject of special attention and efficient disinfection carried out.

Control of post operative sepsis by antibiotics

During the past year the amount of penicillin used as a prophylactic measure in the treatment of sepsis was reduced and the double antibiotic therapy as advocated by Barber et al. (1960) was adopted. It is too soon to estimate whether the number of penicillin sensitive strains of Staph. aureus has increased as it did in the hospital where these observers worked, or whether the number of penicillin-tetracycline resistant strains has decreased, but preliminary results seem promising. As this is a very controversial subject, I hesitate to make a categoric recommendation and there is an important drawback to this form of control, namely that the cost of administering two expensive antibiotics simultaneously makes a big increase in the hospital drug bill and it is debatable whether this sort of expenditure can be justified in view of the call for national economy. Perhaps in the long run it would be better to rely upon other methods of controlling sepsis. Nevertheless in the situation described by Barber et al. where the hospital receives a large proportion of patients from other hospitals who bring with them multiple resistant strains, this type of antibiotic programme is probably justified.

My final recommendation is that all personnel likely to be concerned in the control of sepsis should be educated in control measures as thoroughly as possible. This is best directed by the Control of Infection Officer and should begin in the bacteriology lectures given to nurses in preliminary training school. The need for control should be constantly brought before the remainder of the nursing and auxillary staff and medical personnel of the hospital, and the best way to do this in my opinion, is by arranging a showing of special films on the subject. Several of these have been produced in the past and are easily available. "Sepsis - a communicable disease" made by Johnson and Johnson, or "Phisohex - a study of hands" by Bayer Products Ltd. are two examples.

SUMMARY

1. A review of the literature on post-operative sepsis since the time of Lister to the present day is given.

2. Post-operative sepsis was studied in a series of 2638 operations performed in a provincial group hospital in England between September, 1957 and October, 1960. In the first 1788 operations a sepsis rate of 11.9% was found and in the next 850 it was 7.7%. Virtually 70.0% of the infection was due to Staph. aureus.

3. An account of the measures which were introduced at various points throughout the three years study to control sepsis, is given.

4. In the discussion the effect of these measures is considered and the results obtained compared with those of other investigations. Special reference is made to and reasons offered why it was considered that the majority of infections took place in the operating theatres.

5. Measures are recommended for the control of post-operative sepsis. They are those which have been found useful in this hospital group.

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