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THE BACTERIOLOGICAL INVESTIGATION OF WOUNDS TREATED BY THE CLOSED-PLASTER METHOD

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Although the last war left us with a good general knowledge of the bacterial flora of open wounds, the present increasing use of the closed-plaster method of treatment calls for more information about the special characters and changes of the flora under these peculiar conditions; and it is this type of information that we have aimed at obtaining.

At the outset it was clear enough that completely covered wounds cannot be adequately investigated without devising some means of bacteriological access to the wound as often as desired; and our investigation therefore began with the invention of a transparent window, easy to open and to close again hermetically, which could be incorporated in the plaster casing of any limb. In this we had the advice and collaboration of Prof. Seddon and Messrs. Corry, Foley, and Elliot Smith. One of the results of the work has been the development of a type of window more satisfactory than the first one, which was found to have a bad effect on the surface of the wound directly under it; and we hope that our experience may be of use to other workers in this field.

At the outset we expected a large number of air-raid casualties to be available, but it has been our happy misfortune to have instead only a slow trickle of compound fractures and lacerations such as occur at all times in civil life, with one or two aerial wounds from the surrounding district. Nevertheless, frequent examinations of a few wounds have given some information not available by rarer examinations of many. Up to the present we have made 73 complete analyses from the flora of 10 cases (often with two wounds), first at excision whenever possible, and then at short intervals after the application of the plaster. In the later stages examinations were made at plaster changes and usually, at less frequent intervals, between changes. Windows were not fitted to patients who were up and about.

The subjects investigated all had injuries to the limbs received in road, aeroplane, or machinery accidents (8) or shell-splinter and gunshot wounds (2). All but one had compound fractures. Five of the cases followed from the beginning were operated upon within eight hours of the accident, two at sixteen hours, one at forty-eight hours. Clinical notes are given towards the end of the paper.

Methods

Access to the Wound.—Various types of window have been tried. The ideal opening should fulfil the following conditions: (1) it must not admit extraneous bacteria to the wound either at the time of opening or at intermediate periods; (2) it must allow representative specimens of the

wound flora to be obtained; (3) it must not interfere in any way with the treatment of the wound. To fulfil this last condition it was found by experience that free drainage must be allowed and that an even pressure on the tissues must be maintained: for example, if the under surface of

Diagram of apparatus giving access to the wound surface (measurements in millimetres)

the apparatus is not flush with that of the plaster, oedema occurs in the part of the wound immediately beneath the window. The most satisfactory apparatus so far devised (see diagram) consists of a small cylinder (internal diameter 1.5 cm., height 1.5 cm.) mounted on a square plate (3.5 cm.) bored with a central hole (diameter 1.5 cm.). A piston fits closely into the cylinder; its upper end is flanged

so as to cover the cylinder rim, and a rectangular handle is attached. The whole apparatus, which is made by Mr. S. W. Bush of the School of Pathology, Oxford, consists of "perspex," the parts being cemented together with "perspex" cement. (No doubt other plastic material could be used.) The apparatus is sterilized by immersion in 10% formalin, washed in saline, and applied directly over a portion of the wound. Underlying gauze packing is, if necessary, split just beneath the cylinder in order to give access to the tissues. Plaster is then applied as usual, the cylinder being surrounded but not covered. Samples are obtained by momentary removal of the piston and insertion of a swab. We have always scrubbed up and used sterile gloves, masks, and overalls while taking samples. These samples have proved to be representative of the flora, provided that (1) direct access is obtained to the wound surface; (2) the apparatus lies over the most dependent part of the wound. In all respects the apparatus has proved quite satisfactory.

Bacteriological Methods

Direct microscopical observation of the discharge was made at every examination, and was used both as a check of the cultural methods and as a basis for a rough estimate of the absolute and relative richness of the flora.

Cultivation.—In general the methods of isolation recommended in the Medical Research Council War Memorandum No. 2 have been followed: plating on blood agar incubated aerobically and anaerobically, and cultivation in Robinson's cooked meat medium and in litmus milk. We have, however, modified and extended the methods recommended for the detection and isolation of organisms in the presence of *Proteus*. Samples are plated on two horse-blood agar plates containing 0.04% potassium tellurite and on one nutrient agar plate containing crystal violet (1/50,000). One tellurite plate is incubated anaerobically. On this plate haemolytic streptococci and *Staph. aureus* have been found to develop satisfactorily, usually within twenty-four hours. *Proteus* is either completely inhibited or grows in discrete colonies. This is the lowest concentration of tellurite which we have found to prevent spreading growth with certainty. On one or two occasions it has been necessary to replate the picked coccal colonies on further tellurite medium, but the separation from *Proteus* has nearly always been complete at the first pick. Colonies of *Str. pyogenes* after twenty-four hours' anaerobic incubation are small, black, and haemolytic; hence they are readily detected and picked off. In preparing the medium care should be taken to bring all the ingredients to a temperature of about 45° C. before mixing and pouring. Spontaneous haemolysis often takes place in medium mixed at a higher temperature.

Diphtheroids, as is well known, develop, often in pure culture, on the aerobic tellurite plate. Some strains of *Staph. aureus* and very occasionally other micrococci may also appear, but we have usually been unable to isolate the non-pathogenic micrococci in the presence of *Proteus*. This organism is completely inhibited on the crystal-violet plate, on which *Ps. pyocyanea* grows well, as do some members of the genus *Bacterium*.

Findings

Presence of Pathogenic Organisms.—Toxigenic *Cl. welchii* (Type A toxin) was present in one case (No. III). It was first isolated at the fourth examination, which was made a few days after the first change of plaster. It was re-isolated on two occasions during the succeeding month. Four weeks later it had disappeared, and was not found again. The patient never at any time showed any clinical evidence of gas gangrene.

Haemolytic streptococci belonging to Group A and *Staph. aureus* were each found in seven cases; five of these patients

harboured both cocci. Both these microbes have invariably persisted in the wound from the time they were first observed to the end of the plaster treatment—in one case for a period of nearly seven months. Dr. F. Griffith kindly typed the streptococcal strains on repeated occasions. All but one belonged to well-recognized types of Group A. The remaining strain, which persisted in the wound for six and a half months, reacted to a group serum, F 69. The type originally isolated persisted in each case throughout the period of observation. One Group B strain was isolated from Case X. It disappeared within a few days, and evidently had no pathological significance. It is of some interest that it was detected in the wound within three hours of injury.

Saprophytic Organisms.—A complete list of the organisms isolated in each case, with the period during which they were observed and an estimate of the approximate duration of the infection, is given in Tables I (persistent microbes) and II (microbes tending to disappear from the wound).

TABLE I.—Organisms isolated from Wounds. Pathogens and Persistent Organisms

Organism	Case and Period of Observation ¹	No. of Cases	Approximate Duration
<i>Str. pyogenes</i> , Group A ²	I (19-240), III (8-86), IV (90-115), V (95-117), VII (1-81), VIII (1-51), X (4-65), X (1-8)	7	Indefinite
<i>Str. pyogenes</i> , Group B	I (3-172), V (1-117), VI (50-89), VII (1-81), VIII (1-51), IX (18-31), X (1-65)	1	< 16 days
<i>Staph. aureus</i>	I (3-172), V (1-117), VI (50-89), VII (1-81), VIII (1-51), IX (18-31), X (1-65)	7	Indefinite
<i>Cl. welchii</i>	III (26-46)	1	4-6 weeks
<i>Proteus</i>	II (7-84), III (8-207), IV (50-100)	3	Indefinite
Diphtheroid Type I	V (1-117), VI (50-89), VII (11-81), VIII (23-51), X (4-65)	4	Indefinite
<i>Ps. pyocyanea</i>	I (70-205), II (15-28), III (8-207), VIII (11-33)	4	Variable; few weeks; indefinite

¹ Roman numerals are case numbers. In brackets are the periods of observation in days; day I being the day of the excision operation.

² Types of streptococcus: Case I, Type F 69; Case III, Type 12; Case IV, Type 11; Case V, Type 11; Case VII, Type 11; Case VIII, Type 27; Case X, Type 12.

TABLE II.—Non-persistent Organisms

Organism	Cases	No. of Cases	Duration
<i>Str. viridans</i>	VI	1	< 7 days
<i>Staph. albus</i>	I, III, VI, VII, VIII	5	< 7 days
<i>Micrococcus</i>	I, III, V, VI, VII, VIII	6	< 3 weeks
Diphtheroids other than Type I	I, III, V, VI, X	5	< 7 days
<i>Bacterium</i>	I, II, V, VIII	4	1-6 weeks
<i>Chromobacterium</i>	II	1	< 7 days
<i>Ps. fluorescens</i>	II	1	< 7 days
<i>Bacillus</i>	I, II, III, V, VII, VIII, IX, X	8	1-4 weeks
<i>Cl. sporogenes</i>	II	1	< 3 weeks
<i>Cl. bifermentans</i>	II	1	< 3 weeks
<i>Plectridia</i> (various)	I, II	2	Variable

Since wholly harmless microbes usually disappear within a few days or weeks, it is curious to note the persistence of the diphtheroid "Type I." This is in marked contrast with all the other diphtheroid types, which disappear within a few days. This organism ferments glucose, saccharose, and galactose, but not maltose, lactose, or mannitol. It appears to conform to the Type I of the M.R.C. Committee's list of unclassified corynebacteria (Andrewes and others, 1923). In general, the flora of these plaster-treated wounds does not appear to differ materially from that of open ones of similar type which receive early treatment. The incidence of anaerobic infections (from both sporing and non-sporing organisms) is low in comparison with battle casualties in 1914-18 and in 1940. Anaerobes are not, however, commonly found in air-raid casualties, and such wounds, which receive comparatively prompt treatment, appear to have a flora similar to that observed in our series (Douglas, Fleming, and Colebrook, 1920; Miles and others, 1940).

Time of Introduction of Organisms

"Hospital Infections."—We are satisfied that in normal circumstances no infection of the wound takes place through

the plaster casing. Infection has, however, been shown to occur fairly often during plaster applications. Evidence for these statements is based upon observations made on wounds fitted with windows so that the nature of the flora can be repeatedly observed both before and after the change of plaster. Thus, at the first examination made after changing plaster, species new to the wound were detected in 7 out of 12 samples—11 new species being found. On the other hand, 21 samples taken at subsequent examinations before the next plaster change showed no new species. Of our 10 patients, 4 were proved to have been infected in this way. A fifth also acquired new species during a period when he had no window, and the source of infection could not be tested. The bacteria so acquired are listed in Table III. These observations apply only to examinations

TABLE III.—*New Species appearing after First 15 Days of Treatment*

Organism	Case	Plaster No.	Fate of Organism
A. In Patients fitted with "Window" in Plaster			
<i>Str. pyogenes</i> (Group A) ..	I	2	Persisted > 7 months
<i>Cl. welchii</i> ..	III	2	Disappeared < 63 days
<i>Str. viridans</i> ..	VI	2	" < 19 "
<i>Staph. albus</i> ..	VI	2	" < 21 "
<i>Micrococci</i> (1) ..	VI	2	" < 21 "
<i>Micrococci</i> (2) ..	VI	2	Persisted > 40 "
<i>Bacterium</i> ..	I	2	Disappeared < 50 "
<i>Ps. pyocyanea</i> ..	I	3	Persisted > 135 "
<i>Plectridium</i> ..	I	2	" > 63 "
<i>Bacillus</i> ..	III	3	Disappeared < 57 "
	VI	2	" < 39 "
B. In Patients without "Window" in Plaster			
Diphtheroids ..	V	3 (?)	Disappeared < 39 days
<i>Str. pyogenes</i> ..	V	Uncertain	Persisted
<i>Str. viridans</i> ..	V	"	Disappeared < 48 days

made after the fifteenth day following the accident. During the first fortnight new species appear in the wound, often in considerable numbers. For reasons given below we believe these to have been introduced before or during the first plaster application.

Pre-hospital Infection.—Our observations throw no light at all upon the sources of pre-hospital infection—i.e., whether this is acquired at the time of the accident or by first-aid treatment, etc., as suggested by Hare (1940). We are, however, inclined to think that the majority of infecting organisms in our series were introduced during this period in spite of the fact that they were often not detected in the wound for seven or even occasionally for fifteen days after admission. In other words, there appears to be a very considerable lag in development of many species in wounds which have been thoroughly excised and cleansed within a few hours of the accident. Some species appear to have been permanently removed by this procedure: thus 12 strains of various organisms isolated from the tissues removed at operation never reappeared at subsequent examinations. These were *Proteus* (Case V); *Staph. albus* and other micrococci (Cases I and III, four species; Case V, one species; Case X, three species); diphtheroids (Cases I and III); *Ps. fluorescens* (Case II).

The progressive development of new species during the first fifteen days is shown in Table IV (cases treated within eight hours of the accident) and Table V (cases treated sixteen to forty-eight hours after the accident).

Most of the delayed development takes place in the group treated early. The appearance of new species on the third or fourth day is to be expected in this group, for many species of organisms introduced at the time of injury are likely to be present in numbers too small to be detected at the first examination, carried out only two or three hours later. It will be seen, however, that six species appeared between the third and seventh or eighth days, one between the fourth and tenth, and four between the seventh and fifteenth days—a total of eleven species. (Technical difficulties unfortunately prevented specimens from being

TABLE IV.—*New Species first isolated at Various Times during First 15 Days*

Case	Day 1	Day 3	Day 7	Day 12
I (Débridement 2 hours after accident)	<i>Staph. albus</i> <i>Diphtheroid</i> (1)	0 0 <i>Staph. aureus</i> <i>Diphtheroid</i> (2) <i>Micrococcus</i> (1) <i>Micrococcus</i> (2)	0 0 + + + 0 <i>Micrococcus</i> (3) <i>Diphtheroid</i> (3) <i>Plectridium</i> <i>Bacillus</i>	0 0 + +++ + 0 ++ ++ ++ +
II (Débridement 3 hours after accident)	<i>Bacillus</i> <i>Cl. bifementans</i> <i>Cl. sporogenes</i> <i>Ps. fluorescens</i> <i>Bacterium</i> Sp.	+ + + + + <i>Chromobacterium</i>	+ + + 0 + 0 <i>Proteus</i>	Day 15 + + + 0 0 0 + <i>Diphtheroid</i> <i>Pyocyanus</i> <i>Plectridium</i>
III (Débridement 3 hours after accident)	<i>Diphtheroid</i> (1) <i>Diphtheroid</i> (2) <i>Micrococcus</i> (1) <i>Micrococcus</i> (2) <i>Staph. albus</i>		0 0 0 0 0 <i>Str. pyogenes</i> (Group A) <i>Enterococcus</i> <i>Proteus</i> <i>Ps. pyocyanea</i> <i>Diphtheroid</i> (3)	0 0 0 0 0 ++ 0 + + +
IX (Débridement 2 hours after accident)	Sterile			<i>Staph. aureus</i> <i>Diphtheroid</i> Type I <i>Bacillus</i>
X (Débridement 2 hours after accident)	<i>H. strep.</i> (Group B) <i>Staph. aureus</i> <i>Diphtheroid</i> (3 types other than I)	Day 4 + + 0 <i>Diphtheroid</i> Type I <i>Bacillus</i> <i>H. strep.</i> (Group A)	+ + + + + + + <i>Enterococcus</i>	0 + + 0 + + +

Persistence or disappearance shown by + or 0
The numbers in brackets refer to the different types of the microbe

TABLE V.—*New Species first isolated at Various Times during First 15 Days. Cases operated upon late*

Case	Day 1	Day 4	Day 10	Day 14
V (48 hours)	<i>Staph. aureus</i> <i>Micrococcus</i> <i>Proteus</i> <i>Diphtheroid</i> Type I <i>Bacillus</i>	+ 0 0 + +	+ 0 0 + + <i>Bacterium</i>	+ 0 0 + + +
VII (16 hours)	<i>Str. pyogenes</i> <i>Staph. aureus</i> <i>Bacillus</i>		++ ++ + <i>Micrococcus</i> <i>Diphtheroid</i> Type I	Day 23 ++ ++ + 0 +
VIII (16 hours)	<i>Str. pyogenes</i> <i>Staph. aureus</i> <i>Micrococcus</i> <i>Bacterium</i> <i>Bacillus</i>		+ + + + + <i>Ps. pyocyanea</i>	+ + + + +

Persistence or disappearance shown by + or 0

obtained from all patients during this period.) Although it is possible that these microbes may have been introduced during the process of opening the window, it seems more probable that they were in fact present but undetected at previous examinations. For, on the first assumption, we should have introduced eleven new species in the course of eleven examinations made between the third and tenth days, while no new species has been detected as a result of twenty-one similar examinations made at later periods. The point needs further investigation, for any delay in

bacterial development at this time, when the barrier of granulation tissue is being built up, may be of great benefit to the patient.

Our reasons for thinking that most (though doubtless not all) of the flora is introduced before and not during débridement are that (1) the number of new species is far greater in the early than in the comparatively late cases, and (2) such infection is by comparison rare at subsequent plaster changes.

Pseudomonas pyocyanea

We have paid some special attention to this organism since the suggestion has recently been revived that it may have a beneficial effect upon wounds and, in particular, that it may inhibit the growth of *Str. pyogenes* and *Staph. aureus* (Trueta, 1939). It has been present in four of our cases (I, II, III, VIII), and three of these have persistently harboured haemolytic streptococci in large numbers; two patients had in addition a *Staph. aureus* infection. The evidence does not suggest that the growth of any other organism is influenced by the presence of *Ps. pyocyanea*.

This question is complicated by the existence of many different strains of the species, which differ in colony form, pigment production, and autolytic action. Only one of our strains (Case III) was highly coloured and strongly autolytic. This strain was not associated with a coccal infection. Very large numbers of observations would be required to show whether this was or was not a purely chance connexion.

The following are the clinical notes of the present series of cases.

Case I

Persistent microbes: *Staph. aureus*, *Str. pyogenes* (from day 19), diphtheroid Type I, *Plectridium*, *Ps. pyocyanea* (from day 70).

27/6/40.—A man aged 45 sustained compound fracture of right leg in motor-cycle accident. Admitted to W.M.O.H. 11 a.m. General condition satisfactory; grossly compound fracture, junction of middle and lower thirds of right tibia and fibula. 11.15 a.m., operation: Wound 3 in. x 2 in. on anterior medial aspect; deep wound 2 in. x 1 in. antero-lateral aspect; skin cleaned with soap and water, antiseptic applied to margins of wounds; wound excised, and enlarged to allow removal of extremely lacerated underlying muscle; wound dressed with dry gauze; fracture reduced by manipulation; plaster applied.

8/7/40.—Patient has had a mild serum reaction, with slight rise in temperature. Leg is satisfactory. Plaster changed; wounds show healthy granulations. Slight discharge.

12/7/40.—Temperature elevated. Patient has pain over indurated area in perineum. This area gradually subsided without incision. Patient continued to run a mild evening temperature, up to 100°. Leg satisfactory.

30/7/40.—Plaster changed. Both wounds smaller in size, full of healthy granulation tissue. Fresh plaster applied. Two days following change of plaster patient had temperature up to 102° and general malaise.

2/8/40.—Temperature normal. No complaints.

29/8/40.—Plaster removed. Wounds healing well. Moderate discharge. No local inflammation. Again, following this change of plaster, patient had brief period of temperature up to 102°, which rapidly subsided.

5/9/40.—Patient allowed up, with crutches.

16/12/40.—Plaster removed. Clinically, union sound; both wounds almost completely healed. Radiographs show small sequestrum, which was removed.

16/1/41.—Wound healed. Union firm. Patient up with crutches, bearing weight.

Case II

Main persistent bacteria: *Proteus*; two clostridia? non-pathogenic; diphtheroid Type I; also, intermittently, haemolytic streptococcus (seen four times but never isolated), and *Ps. pyocyanea*.

Man aged 21, injured in bomber crash. Compound fracture of lower third of tibia; also compression fracture of fourth cervical vertebra (discovered later) and minor injuries.

20/7/40.—Operation 2½ hours after accident. Cleansing and débridement of leg wound 6 in. x 3 in. in size, exposing 5 in. of tibia; full of dirt. Suture of upper third; plaster, with window. Sulphapyridine, 1 gramme i.m. 4-hourly.

21 and 22/7/40.—No significant rise of temperature. Sulphapyridine continued by mouth (0.5 gramme 4-hourly on 22nd), then discontinued.

29/7/40.—Steady improvement without fever. Plaster smelly.

9/8/40.—Plaster changed; good progress in healing.

28/8/40.—"Zimmer distraction" under spinal anaesthesia. Good position of bone achieved (plaster presumably renewed). No subsequent fever.

28/9/40.—Progress has been smooth; pins removed (plaster presumably renewed).

6/10/40.—Plaster removed. Wound healing well.

8/10/40.—Clinical evidence of bony union. Radiological report: "No sound union; some osteitis."

15/10/40.—Transferred.

Case III

Persistent microbes: *Str. pyogenes*, *Proteus*, *Ps. pyocyanea*.

At about 6 p.m. on August 23, 1940, a man aged 24 was involved in a motor-cycle accident and sustained injuries to the right leg. He was admitted to Radcliffe Infirmary and found to be suffering from compound fracture of right patella, compound supracondylar fracture of right femur into knee-joint, and extensive laceration of skin and muscles of lower part of thigh. There were no other injuries.

Operation was carried out at 8.45 p.m. under general anaesthesia. The skin was scrubbed with soap and water and shaved. The edges and all devitalized tissue were then excised, including the patella, which was in many small fragments and impregnated with road dirt. The cavities created by this thorough excision of the wound were lightly filled with dry gauze and the limb was encased in a plaster spica.

For about forty-eight hours the patient's condition was very good. He had little pain in the limb and no pyrexia. Then his temperature shot up to 104° and he began to complain of pain around the knee. He was immediately put on sulphapyridine and given 16,000 units of anti-gas-gangrene serum intravenously. A small window was cut in the plaster above the wounds so that the condition of the leg could be seen. There was more than an inch between the skin and the plaster, but no suggestion of gas in the tissues. The temperature settled a bit, but continued to swing up to 101° in the evenings. The plaster was removed on September 9 and a large pocket of pus was found tracking well up on the posterior aspect of the thigh. The large abscess was drained by a postero-lateral incision into its most dependent part.

Since that time the problem has been entirely one of drainage. The patient has had repeated changes of plaster and three operations for removal of sequestra and for drainage. Since the first three weeks his general condition has never given rise to any anxiety. At the time of writing his wounds are reduced to two sinuses, which are healing. The union of the fracture is unsound because of the removal of a large sequestrum.

Case IV

Persistent microbes: *Str. pyogenes*, *Proteus*.

17/5/40.—A man aged 34 sustained a technically compound fracture of the right femur following a bomb explosion. Was operated on at Bruges three hours later. Wound was sutured without exploration and plaster spica applied.

29/5/40.—Admitted to Pembury Hospital. Skeletal traction with Kirschner wire through lower end of femur on Thomas splint.

8/6/40.—Plaster spica applied.

10/6/40.—Admitted to W.M.O.H. Ill man; high temperature. Toes swollen.

17/6/40.—Plaster removed under general anaesthetic. Original wound opened. Large abscess evacuated. Sequestrum removed. Counter-drainage effected. Thomas splint, with strong traction, applied.

27/6/40.—Drainage improved. Plaster applied.

5/8/40.—Plaster changed under general anaesthetic. Wound healing. General condition satisfactory.

5/9/40.—Plaster removed. Pin inserted through tibial tubercle. Traction and Thomas splint to correct slight overlap.

9/9/40.—Position satisfactory. Plaster spica applied.

7/11/40.—Plaster changed. Wound clean; healing.

20/12/40.—Dressings changed. Two sequestra removed.

10/1/41.—General and local condition satisfactory.

NOTE.—This has been a problem of drainage from the beginning; each rise in temperature and deterioration in general condition has been associated with retention of pus, and has improved following the institution of adequate drainage.

Case V

Persistent microbes: *Staph. aureus*, *Str. pyogenes* (from day 95), diphtheroid Type I.

11/9/40.—9 a.m.: This patient, a youth aged 16, caught his arm in a machine, and was lifted up by the limb. Admitted to High Wycombe Hospital, and found to have compound dislocation of left elbow and compound fracture of both bones of forearm. 1 p.m.: Dislocation reduced under general anaesthetic; excision of wound; vaselined gauze, dressing, and plaster applied. 5 p.m.: Admitted to W.M.O.H. On examination, mild shock. Plaster splint; wound 4 in. long inner medial side of lower end of humerus. Apparently little loss of skin, but wide separation of edges. First dressing and bivalved plaster applied.

13/9/40.—General condition satisfactory. Plaster removed under general anaesthetic. Wound cleaned. Small wound on ventral surface of forearm opened. Some necrotic muscle excised. Dry dressing applied to both wounds. Fresh plaster.

1/10/40.—Discharged home in plaster.

24/10/40.—Plaster removed. Both wounds healing well, and filled with clean granulation tissue. Moderate discharge. Radiograph shows good alignment and early union of forearm fracture. Loss of joint space. Apparently beginning destruction of elbow-joint.

21/11/40.—Plaster changed. Condition as above, with further progress of healing.

17/12/40.—Patient readmitted with fever and some pain in the arm. History: On 3/12/40, while in quarantine for scarlet fever, he had a sore throat and pyrexia, and complained of pain in the elbow. Plaster was split and the wound inspected. He was given sulphanilamide for three days, and condition subsided. On 15/12/40 he again complained of pain, and had a rise of temperature.

On admission the temperature was 104°, with some swelling of the hand; no other signs with regard to the arm. The throat was inflamed and the right tonsil large and oedematous. Plaster changed; wounds healthy; no increase in discharge; no retention of pus. Fresh plaster applied.

19/12/40.—Temperature normal. No complaints. The administration of sulphanilamide was discontinued.

15/1/41.—Seen as out-patient. Has been free from pain and pyrexia since discharged from hospital. Plaster off. Wound of forearm healed. Good progress of healing of elbow wound. Radiographs show firm union of forearm fracture. Increase in destruction of elbow-joint. Plaster reapplied.

5/3/41.—No complaints. Plaster removed. Elbow wound healed except for small sinus. Little discharge.

Case VI

Persistent microbe: *Staph. aureus*.

16/8/40.—5 p.m.: Patient, a man aged 40, had left leg injured as result of enemy action. Admitted to Radcliffe Infirmary. Found to be suffering from very extensive lacerations of calf of left leg, from popliteal space to lower part of tendo Achillis. Large area of skin and underlying muscle shot away. 9 p.m., operation: Skin cleansed with soap and water; antiseptic applied to margins of wound; normal excision of wound, which involved excision of greater part of gastrocnemius, leaving soleus fascia exposed; following excision, dry gauze applied to wound and plaster to mid-thigh. Patient had no rise in temperature, with exception of 100.2° on 17/8/40, and made no complaint of his leg. Plaster was left untouched for seven weeks.

5/10/40.—Plaster removed. Some pus inside plaster; the gauze was removed with difficulty from wound, owing to granulations having grown into it. Wound was clean, granulating well. Fresh plaster was applied. Following this change of plaster there was no rise in temperature and no pain in the leg. Skin graft applied.

25/11/40.—A section of full-thickness skin 3 in. × 1 in. was taken from posterior aspect of left thigh. This wound was sutured, and the piece of skin removed was cut into a large number of small pieces and applied to the granulating surface. Vaselined gauze dressing applied.

18/12/40.—Whole area covered with thin layer of skin.

Case VII

Persistent microbes: *Staph. aureus*, *Str. pyogenes*, diphtheroid Type I.

20/10/40.—Motor-cycle accident, 10.30 p.m., to school-master aged 21. Admitted to Wantage Hospital. Injuries to face, right hand, and right leg. Sterile dressings applied to wound. Laceration of face sutured.

21/10/40.—Admitted to W.M.O.H. General condition satisfactory. Marked contusions of right hand without frac-

ture. Abrasions on dorsum. Oblique compound fracture right tibia and fibula, junction of middle and lower thirds, with wide separation. 3 p.m., operation: Wound 2½ in. × 1½ in. on postero-medial aspect of leg, with muscle protruding; skin carefully cleaned with soap and water, and margins of wound painted with antiseptic; wound enlarged to permit exploration of surrounding muscle; all dead muscle excised; wound dressed with dry gauze, fracture reduced by manipulation, and plaster applied with a perspex window over wound.

25/10/40.—No complaints re leg. Some cough and physical signs in left chest. Temperature 100°. Given sulphapyridine; 2 grammes initial dose, then 1 gramme four-hourly.

30/10/40.—Condition satisfactory. Slight rash over arms and trunk. Sulphapyridine discontinued.

15/11/40.—General condition good. Temperature within normal limits for past fifteen days. Plaster changed under general anaesthetic. Wound clean and granulating well.

18/11/40.—Patient allowed up with crutches.

24/11/40.—Patient had two days' fever, general aches and pains. Diagnosed influenza. Temperature again normal, no complaints.

13/12/40.—Plaster changed. Wound clean, granulating well. Slight excoriation of skin. Radiograph shows some callus formation.

21/12/40.—Discharged from hospital.

6/2/41.—Plaster changed. Wound almost healed. Clinically, fracture has united in satisfactory position. Radiograph shows good callus. Short plaster applied.

Case VIII

Persistent microbes: *Staph. aureus*, *Str. pyogenes*, diphtheroid Type I, *Ps. pyocyanea*.

20/10/40.—Motor-cycle accident to man aged 26. Admitted to Cottage Hospital with injuries to left hand and right knee. Sterile dressings applied to wound.

21/10/40.—Admitted to W.M.O.H. General condition satisfactory. Multiple abrasions dorsum of left hand. Large open wound right knee, with fracture lateral margin of patella. 3 p.m., operation: Wound about 4 in. × 3 in., ragged, with considerable loss of skin; skin of leg and thigh cleansed with soap and water; margins of wound painted with antiseptic; wound excised, including damaged muscle and fragment of patella; following excision of wound, knee-joint was closed with interrupted catgut sutures; wound dressed with dry gauze, and rubber drain inserted through stab wound to effect dependent drainage.

22/10/40.—Following the operation, the plaster was applied from high up in the groin to the ankle. Sulphapyridine, 2 grammes initial dose, 1 gramme four-hourly, was started. No complaints. Temperature 100.8°.

25/10/40.—Temperature normal. No complaints. Sulphapyridine discontinued.

14/11/40.—Plaster removed. Wound clean, granulating well. No infection in knee-joint. Fresh dry dressing and plaster applied.

22/11/40.—Since last change of plaster, patient has made no complaint. Temperature has been normal. Plaster changed. Wound healing well.

17/12/40.—Plaster bivalved. Local dressing of sulphanilamide powder applied.

20/12/40.—Secondary suture of wound. Following plastic operation and suture, moderate rise of temperature for four days, which settled down when a haematoma was evacuated from lateral side.

25/12/40.—Temperature normal. No complaints.

11/1/41.—Wound healed. Patient walking well.

Case IX

Persistent microbes: *Staph. aureus*, diphtheroid Type I.

14/11/40.—A man aged 45 had his right leg injured in a motor-cycle accident. Admitted to W.M.O.H. 5 p.m. with compound fracture of right tibia and fibula at junction of middle and lower thirds. At 5.30 p.m., under general anaesthesia, the wound was exposed. It was found to be a puncture about 2½ in. × 1 in. The skin was cleansed in the usual manner and the wound edges excised; all underlying muscle was viable, and only a small quantity of subcutaneous tissue was excised. Dry dressing; fracture reduced by manipulation; plaster applied.

16/12/40.—Since the operation the general and local condition of the patient has been satisfactory. No pain in leg and no pyrexia. Plaster changed; wound almost healed; little evidence of union of fracture. Fresh plaster applied.

4/1/41.—No complaints. Up on crutches without weight-bearing.

5/2/41.—Plaster changed; very small area not covered by skin. Union progressing; plaster applied below knee.

Case X

Persistent microbes: *Staph. aureus*, *Str. pyogenes*, diphtheroid Type I.

20/1/41.—At 7.45 p.m. patient, a man aged 61, was knocked down by a bus. Admitted to W.M.O.H. at 8.5 p.m. Found to have compound fracture of upper third left tibia and fibula, with extensive violence to the skin, and a large wound in the popliteal space. No loss of skin on posterior aspect. Medial dislocation of left ankle. General condition satisfactory. 9.50 p.m., operation: Skin cleansed with soap and water; antiseptic applied to margins of wound; the extensive wound of the back of the leg was excised and the skin sutured; the fracture and dislocation of the ankle were reduced by manipulation; dependent drainage was effected by means of rubber tubes through the stab wound. Plaster was applied.

26/1/41.—Patient has had no pain in the leg. Rise in temperature and respiration rate and some sputum. Has been on sulphapyridine for the past five days. General and local condition now satisfactory.

5/2/41.—Plaster changed because of profuse discharge. On removal it was found that the posterior wound was satisfactory, but that a large area of damaged skin on the upper anterior surface of the leg had separated and was lying as a free slough. This was removed. Wound dressed and fresh plaster applied.

21/2/41.—Patient has been running slight evening rise of temperature, but has made no complaint with regard to the leg. Considerable discharge from plaster. Plaster removed. Posterior wound well healed, anterior wound shows large clear area of granulations, about 6 in. long by 4 in. wide. No surrounding infection. Following change of plaster patient had no rise of temperature. General and local condition satisfactory.

Discussion

The cases investigated were selected from a much larger series as being suitable for complete bacteriological examination from the earliest stages to the final healing. One of us is in process of analysing the clinical aspects of the larger series as a whole. Neither the general composition of the wound flora under closed plasters nor the changes of its composition in the early or later stages have given any clear explanation of the virtue of the closed-plaster method of treatment. We have found no striking difference in flora between our wounds and the open wounds described (Miles and others, 1940) during the present war. We have not seen, as we thought we might see, a disappearance or diminution of pathogenic bacteria under the influence of saprophytic anaerobes or of relatively harmless Gram-negative aerobic rods such as *Proteus* or *Ps. pyocyanea*.

Although it is impossible to assert that *Str. pyogenes* (Group A) is completely innocuous in properly immobilized and protected wounds, it is clear enough that this microbe may be present from first to last in wounds which, under these conditions, heal without obvious complications or gross delay; and the same is true of *Staph. aureus*. But these phenomena, it seems, may also be seen sometimes in open wounds.

The method of treatment, we feel, owes its efficacy rather to its physical and physiological effects than to any specific influence on the bacterial flora (Trueta and Barnes, 1940).

The window-sampling method has proved satisfactory when true access to the tissues is provided, and has enabled us to observe changes in the flora at all periods of treatment and to form provisional views about the reasons for the appearance and disappearance of species, and about the protection afforded by the plaster against gross infection.

Summary

A satisfactory method has been devised for securing bacteriological samples from wounds encased in plaster without interfering with the treatment.

The flora of wounds treated in closed plaster does not appear to differ from that of open wounds, and neither its character nor its fluctuations explain the efficacy of the closed-plaster method. Infection of such wounds during the period of hospital treatment occurs fairly often during changes of plaster, but no cross-infection has been detected at any other time.

It is suggested that the multiplication of bacteria is delayed for some days in wounds which are excised and cleansed within a few hours of the accident. Some organisms appear to be permanently removed by this procedure.

No evidence has been found that *Ps. pyocyanea* or any other organism inhibits the growth of haemolytic streptococci or of *Staph. aureus* in wounds.

The Medical Research Council has provided a part-time grant for one of us (J. O.-E.) and a whole-time salary for a laboratory assistant (W. Fincham), as well as money for expenses. Prof. Gardner owes his leisure for research partly to the University of Oxford and partly to the Nuffield Trust. Prof. H. J. Seddon and Prof. H. W. Florey played a large part in launching the research, and Mr. Elliot Smith collaborated on the surgical side during the early stages. Dr. F. Griffith, whose death we lament, kindly typed our streptococci, and Prof. A. A. Miles struggled nobly and successfully with our anaerobes.

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DIABETIC COMA IN A SERIES
OF YOUNG DIABETICS*

BY

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This clinical study of diabetic coma is based on a series of 24 young diabetics who have attended Addenbrooke's Hospital during the last twelve years. Some of these cases have already been referred to (Cole, 1934). In 23 the disease came on before the age of 15, and in one patient, aged 18, coma was the first symptom. After standardization as in-patients they have attended as out-patients at intervals of from one to three months until the time (1939) when this study was completed (or in fatal cases until death). With the exception of Case 24 they are unselected and comprise all the diabetics attending my department between 1927 and 1939 who were under 15 at their first attendance. Four live in Cambridge and the remainder in towns and small villages within a radius of fifty miles, often at considerable distances from their doctors, and when complications such as infections or coma develop there is often some delay before they can be treated or be admitted to hospital. A series of young diabetics has been chosen for this study because in youth the results are less likely to be complicated by chronic intercurrent disease.

Incidence of Coma

Table I shows that in 24 diabetics coma occurred 13 times: 7 patients had one attack and 3 had two. In 6 coma was the first recognized symptom of diabetes, and in 7 it occurred during the course of treatment. The whole series covers a period of 165 diabetic years, giving an average of approximately one attack every thirteen years for all cases, including patients who had had no treatment before coma. In cases under treatment with insulin the average was one attack every twenty-three years. These figures are quoted to show the incidence in a small group of patients living under somewhat similar conditions and treated on similar lines.

Table II indicates the possible causes of coma. In 6 out of 13 instances the attack occurred in patients in whom diabetes had not been previously diagnosed, and in 4 of these its onset coincided with an infection. In the remain-

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