4 p.m.—Condition improved. Complete excision of wound, sulphanilamide pack, vaselined gauze, immobilization on Thomas splint with pins above and below fracture.

November 16.—Condition fairly good. Pulse still irregular—100 and poor volume.

November 17.—Definitely improving. Pulse still irregular. At 10.30 p.m., pulse 130. Wound examined. No local evidence of gas infection.

November 18, 3.30 a.m.—Pulse 120. Some crepitus in region of wound. Toes cold though not gangrenous. Plasma with 6 c.cm. of sulphapyridine and 20,000 units of polyvalent anti-gas-gangrene serum given.

6 a.m.—Asthmatic attack. (Patient subject to recurrent asthma.) Pulse 160. Oxygen given with B.L.B. mask. Adrenaline 80 minims given slowly and intramuscularly. Gross gas infection of leg present.

8 a.m.—Slight improvement in general condition, but gangrene spreading.

9 a.m.—Extensive gas gangrene below knee. Asthma controlled, but pulse still 130 and general condition very poor indeed. Blood transfusion given. Amputation through lower third of thigh in bed.

1.30 p.m.—Pulse 96. Condition improved. Steady gradual improvement from this stage.

All my colleagues and I feel certain that if either of these patients had been moved from his bed or from the ward his chances of recovery would have been seriously diminished.

Summary and Conclusions

It is suggested that the performance of amputations in the patient's bed, in the ward, the theatre, or his own house, may be the deciding factor in saving life, since the operation can be done with the least possible disturbance to the patient.

A simple technique for amputations in bed is described.

DOUBLE INFECTION OF THE MENINGES WITH MENINGOCOCCUS AND GAERTNER'S BACILLUS

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The following case seems worth recording for two reasons—first, because it is extremely uncommon for a child to recover from one variety of meningial infection only to fall a victim to another; secondly, because the type of meningitis which proved fatal is in itself comparatively rare. The primary infecting strain was meningococcus, the secondary *Bact. enteritidis* (Gaertner's bacillus).

Clinical Summary

A female infant aged 14 months was admitted to the Royal Hospital for Sick Children on June 16, 1940. She had been well until three weeks previously, when she became feverish, listless, and drowsy, began to refuse feeds, and vomited on several occasions. On June 15 the child had a convulsion. On admission to hospital she was flushed, with staring eyes, and had a marked "meningeal" cry. There was evidence of increased intracranial pressure, so lumbar puncture was performed. The fluid was under slightly increased pressure and was turbid; the cell count was 630 cells per c.mm., and films showed that these were both polymorphonuclear and lymphocytic. Meningococci were seen, mostly lying free, though a few were intracellular. On culture a heavy pure meningococcal growth was obtained. The child was transferred to Ruchill Fever Hospital on June 17. There the above

findings were confirmed. Blood culture was negative. Treatment with sulphathiazole was instituted, and she received 20 c.cm. of sodium sulphathiazole intramuscularly and 0.75 grammes of sulphathiazole four-hourly by mouth. Lumbar puncture forty-eight hours after admission showed a clear fluid in which no meningococci were found in smears or on culture. She received 26.5 grammes of sulphathiazole in eight days, when the drug was stopped. The temperature settled within forty-eight hours of starting treatment, and progress was uneventful for almost a fortnight. On July 2, however, it was noticed that the patient was fretful and that the eyes were staring and wild-looking. There was occasional twitching of the eyes. Examination showed a paralysis of conjugate upward movement of the eyes and of conjugate movement to the right. The pupils were semi-dilated and did not react to light. An internal hydrocephalus was suspected. On July 8 there was a sudden rise of temperature to 107° F., and lumbar puncture was performed. Films showed abundant motile Gram-negative bacilli, and these were obtained in pure culture, the growth on MacConkey plates consisting of non-lactose-fermenting colonies. The child died twenty-four hours later. Necropsy showed fine adhesions between the pia and arachnoid, with considerable flattening of the convolutions. There was much inflammation of the surface of the brain, over which was a thin purulent exudate, mainly vertical. The ventricles were greatly dilated and contained thin purulent fluid.

Bacteriology

Cultures yielded a pure non-lactose-fermenting growth similar to that already obtained from the cerebrospinal fluid. Several colonies subcultured produced acid and gas in glucose, mannite, maltose, and dulcitol, and failed to ferment lactose and saccharose. No indole was formed. A polyvalent Salmonella antiserum (Oxford standards) agglutinated cultures to titre. The strain was then tested against the various O (somatic) antisera of the Salmonella group, when agglutination occurred with *Bact. typhosum* O antiserum. This fact, taken in conjunction with the fermentation reactions, suggested that the strain was a member of the *enteritidis* group, which shares with *Bact. typhosum* the O antigens IX and XII. A further series of biological tests similar to that employed by Guthrie and Montgomery (1939) was next undertaken, the unknown Ruchill strain being tested in parallel with a known culture of *Bact. enteritidis* and of its closely related Dublin variant. The Ruchill culture behaved in every respect like the *Bact. enteritidis* strain. Confirmatory serological tests were then performed, when an antiserum prepared to the Ruchill strain agglutinated the homologous organism and several known *enteritidis* cultures to approximately the same high titre. Similarly a stock *enteritidis* antiserum agglutinated in high and approximately similar dilutions several known *enteritidis* strains and the Ruchill organism. Finally, the flagellar antigenic formula of the Ruchill culture was determined by the method of Kauffmann (1935-6). As already stated, it possessed the O (somatic) antigens IX and XII. Its H (flagellar) antigens were found by performing direct agglutination tests with antisera containing individual flagellar antibodies, employing the procedure described in detail by Guthrie and Montgomery. In common with various stock *enteritidis* cultures tested in parallel the Ruchill organism was found to possess the flagellar fractions g and m. Thus the serological, like the fermentative, reactions were those of a true *enteritidis* strain. The organism proved toxic for a rabbit, which succumbed within forty-eight hours of receiving an intravenous inoculation of 1/10 of a fresh agar culture suspended in saline. At necropsy the infecting strain was recovered in pure heavy growth from the heart blood, swollen spleen, and bile. The intestinal contents also were heavily infected.

Discussion

Few examples of double meningial infection such as ours are to be found in the literature. A closely similar case is that reported by Opitz (1919) in a child of 15 months in whose cerebrospinal fluid meningococci alone were present originally. Subsequently Gram-negative bacilli appeared in films of the ventricular fluid, and a strain later identified as *Bact. enteritidis* was obtained on

culture. Welcker and Vogl (1938) also record a double infection of the meninges. Their patient, a female infant, was admitted to hospital with meningococcal meningitis, which improved under treatment; but a relapse occurred after a fortnight, when a *Salmonella* strain—in this instance *Bact. typhi murium*—was obtained in pure culture from the cerebrospinal fluid during life and at necropsy. Ravitch and Washington (1937), in the case of a 4-year-old girl, isolated meningococcus in pure culture from both the cerebrospinal fluid and the blood on the day of admission to hospital. A second blood culture taken twenty-four hours later gave a pure growth of *Bact. suipestifer* (the hog-cholera bacillus), and on the fourth day this organism alone grew from the cerebrospinal fluid. The authors considered, however, that as the spinal fluid was grossly contaminated with blood in the course of withdrawal the *suipestifer* strain may have been introduced in this way. Reid and Lipscomb (1940) saw streptococcal followed by pneumococcal infection after an interval of some months in a girl of 17. Both attacks of meningitis complicated mastoiditis.

A possible explanation of such double infections may lie in the fact that a primary inflammation of the meninges, by affecting the local capillaries and increasing the permeability of the endothelium, may predispose to a secondary meningeal infection. Burrows (1932) collected numerous instances of the localization of bacteria in injured or inflamed areas, which thus show lessened resistance.

Apart from its association with meningococcus, *Bact. enteritidis* as a cause of meningitis is of interest for its own sake, since organisms of the *Salmonella* group are among the rarer meningeal invaders. Comparatively few records of *Salmonella* meningitis are extant in the literature, and of these the great majority have appeared within the last decade. Most of the reports describe single examples, but series of collected cases are published by Lynch and Shelburne (1930), Bahrenburg and Ecker (1937), and Guerra *et al.* (1940). The last-mentioned authors' series is the largest, numbering 60 cases. Various *Salmonella* types have been incriminated—*Bact. paratyphosum* A (Eckert, 1910); *Bact. paratyphosum* B (Voigt, 1922; Brahdy, 1925; Anderson, 1932); *Bact. suipestifer* (Boycott and McNee, 1936; Clifton and Werner, 1938); *Bact. aertrycke* (Aballí *et al.*, 1937); *Bact. panama* (Katsampes and Bradford, 1940). Although these examples show that the *Salmonella* group as a whole possesses considerable powers of invasion, two members in particular are believed to have a special predilection for the meninges—*Bact. enteritidis* and *Bact. enteritidis* var. Dublin. Guthrie and Montgomery during a recent outbreak of *enteritidis* infection in young infants saw 10 cases with frank purulent meningitis due to this organism and 1 caused by the Dublin bacillus. They quote other examples.

The most striking fact concerning *Salmonella* meningitis which emerges both from our personal experience and from a survey of the literature is its marked tendency to affect infants—especially those in the neonatal period—rather than older children or adults. Nearly all the single case reports quoted concern babies under the age of 1 year, in whom meningitis was a sequel to *Salmonella* invasion of the blood stream, which occurs more readily in very early life than at any other age period. In fact, in young infants *Salmonella* infections tend to produce lesions quite distinct from those typically seen in adults. Similarly, young animals of various species are particularly susceptible to *Salmonella* infections (Hormaeche, quoted by Zerbino *et al.*, 1940), and septicaemia with purulent complications due to the Dublin bacillus has been described in young calves by Bosworth and Lovell (1931).

Infection apparently enters by way of the alimentary tract. Gross intestinal lesions do not, however, necessarily precede invasion of the blood stream. Sometimes, in fact, the gastro-intestinal tract appears normal, as in the present instance and in the cases of Symmers and Wilson (1908-9), Smith (1921), and Pesch (1926). Also Guerra *et al.* (1940), who with others have extensively investigated *Salmonella* infections in Uruguay within recent years, found evidence of enteritis only in the minority of their fatal cases. They suggest that, as in other meningeal infections, the portal of entry is pharyngeal, with subsequent invasion of the blood stream and localization in the meninges.

The origin of the *enteritidis* strain was not discovered in our case. As the organism was isolated from our patient for the first time three weeks after admission to hospital it was thought possible that she might have been infected from another patient. Specimens of faeces from all the other inmates of the ward were therefore examined, but all were negative. Inquiry elicited no history of diarrhoeal disease either in the child's family or in any member of the nursing staff before the onset of her illness. In infants contaminated cows' milk must be considered a likely source of *Salmonella* infection, particularly in the case of *Bact. enteritidis* and the Dublin bacillus, since these strains are among the commonest *Salmonella* invaders in cattle (Bosworth and Lovell, 1931), and at least two epidemics have been traced to infected milk (Kinloch, Smith, and Taylor, 1926; McAllan and Howie, 1931). In the present case the milk supply could be excluded as a source of infection, since it was a bulked certified milk and was supplied to a large number of infants without mishap. The source of sporadic *Salmonella* infections often remains obscure, and difficulty in incriminating milk or some other article of food as a vehicle of infection may depend partly at least on the varying resistance of those consuming it, since even a small inoculum may produce disease in subjects so peculiarly susceptible as young infants, while a much larger dose may be borne with impunity by older individuals.

Summary

A case of double meningeal infection in a child is reported and the bacteriology of the condition is discussed.

The literature is given of the few other cases that have been placed on record.

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