THE AETIOLOGY OF PUERPERAL INFECTION

WITH SPECIAL REFERENCE TO DROPLET INFECTION *

BY

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Since there is now little doubt that haemolytic streptococci cause the greater part of severe puerperal morbidity, recent workers have largely investigated the methods by which these organisms are introduced into the genital tract.

FitzGibbon and Bigger (1925), and Burt-White and Armstrong (1928), showed that the *Streptococcus haemolyticus* was a rare inhabitant of the vagina of the pregnant woman, and deduced that infection by this organism was almost always exogenous. Kanter and Pilot (1924) were the first to suggest that haemolytic streptococcal puerperal infection could be caused by droplet infection. Meleney and his co-workers supported this view. King (1930) showed a close correlation between the fluctuations of haemolytic streptococcal puerperal infection and of throat infection.

Throat Carriage

It is well known that haemolytic streptococci are found in the throats of apparently normal people, but the percentage of throat carriers varies with different observers (Table I). The Jessop Hospital, Norton, figures, giving

TABLE I

Author	Total Swabs	Percentage of Carriers of Haemolytic Streptococci	
		Nasopharynx	Tonsils
Blackburn et al., 1930	412	7.77	
" "	137	5.84	5.11
" "	252	11.90	
Williams, Nevin, and Gurley, 1921 ...	75		8.0
Paine (unpublished) †			
Group 1... ..	885	26.2	
Group 2... ..	197	47.7	
Manchester investigation :			
Group 1, with colds	110	17.27	
Group 2, without colds	1,731	13.23	
Grand total of swabs	3,799	17.05	

† Group 1 comprised all patients on admission to hospital. Group 2 comprised members of the hospital staff.

a higher percentage than the others, were obtained from the results of swabs from patients on admission over a period of three and a half years; each swab was taken as a sweep of the nasopharynx and both tonsils. Roughly, one in four of an urban population harbours this organism.

The relation between the seasonal variation of haemolytic streptococcal puerperal infection and that of throat carriage has been examined during this period, and a well-defined correspondence is seen between the two (Graph A, p. 244). The peak of infection occurs about April of each year; the graph also supports the observation of Williams (1932), who showed that the curve of incidence of puerperal infection followed that of respiratory infection.

Statistics thus indicate that throat carriage is related to haemolytic streptococcal infection in the puerperium. Are patients infected from their own throats or from the respiratory tracts of attendants? The figures shown in Graph B (p. 244) in part elucidate these points.

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This graph, giving the incidence of haemolytic streptococcal cervical infection among patients with positive throats, shows the same seasonal variation noted between the gross figures in Graph A. If patients with haemolytic streptococcal cervical infection habitually infected themselves from their own throats, then a graph approximating to a line parallel to the horizontal axis would be expected. This same seasonal variation must be taken as an indication that genital infection is not homo-exogenous but hetero-exogenous—that is, from the respiratory tracts of obstetric attendants.

This argument is supported by serological work of various observers, who show that haemolytic streptococci recovered from the respiratory tracts of obstetric attendants are to a large extent identical with those from patients' genital tracts (Table II). Of sixty-two cases of

TABLE II

Case Classification	Smith, 1931	Paine, 1931	Courmont and Sedallion, 1931	Smith, 1933	Paine (unpub.)	Edgington (unpub.)	Total
No. of cases of haemolytic streptococcal uterine infection	18	2	6	31	4	1	62
No. of cases with source of organism of serological identity in upper respiratory tract of obstetric attendant	12	2	6	18	3	—	41
No. of cases with source of organism of serological identity in upper respiratory tract of patient	1	—	—	7	—	1	9
No. of cases with source of organism of serological identity in septic focus elsewhere	2	—	—	—	—	—	2
No. of cases with source undetermined	3	—	—	6	1	—	10

haemolytic streptococcal uterine infection, in forty-one organisms identical with the genital strain were present in the throats or nares of the obstetric attendants, who were presumably responsible for infecting them. It might be suggested that the attendant had infected his own throat from the patient's genital tract, thus accounting for the identity of the strains. This can be refuted by considering that among the cases recorded are groups associated with one attendant, who harbours organisms in his throat identical with the strain common to the genital tracts of the members of the group. Of sixty-two cases nine had organisms in the throats identical to those in their own cervixes. Again it might be argued that throat infection followed uterine infection. This cannot at present be refuted, but one observation, by Edington (personal communication), merits recording in this regard.

CASE RECORD

Mrs. S. was admitted to hospital on April 25th, 1933, two days before delivery, suffering from sore throat. Swabs were taken from the fauces and cervix on that date. The temperature rose thirty hours after delivery (April 28th), and a second cervical swab was taken.

Bacteriological Findings.—April 26th: cervix—yeast and *B. subtilis*; throat—haemolytic streptococci and other organisms. April 29th: cervix—yeast and haemolytic streptococci. Reciprocal agglutinin-absorption tests showed the strains from both sources to be identical. There can be no doubt that she infected her own genitalia from her own throat.

This survey affords strong evidence that haemolytic streptococcal throat carriage is a very important source of infection to parturient women. The incidence of genital infection by organisms from the patients' own throats appears to be much smaller. There is, however, some difference of opinion as to how infection travels from such an external source. Colebrook (1933) doubts whether haemolytic streptococci can be sprayed from the mouth when there is no obvious tonsillitis, and quotes experimental evidence in support. Tests similar to his have been done in the present investigation. In a series of

fourteen, wherein subjects known to harbour these organisms in the throat without clinical signs were asked to cough at blood-agar plates held a few inches from their mouths, four positive results were obtained: but when shallow dishes containing 10 per cent. blood broth were exposed ten positives were obtained. Similar tests, holding the dishes ten inches in front of the chin, gave only one positive. This shows that spraying did occur, but that the momentum of the droplets was low. Colebrook suggested that soiling of the hands by nasal secretions from the handkerchief is a more probable method of transference. In one case here investigated there seems to be no doubt that direct spraying from the throat was the actual method of transference. In this case, recorded since the underlying principles are the same, the patient developed peritonitis following a laparotomy.

CASE RECORD

Mrs. M., aged 42, was admitted to hospital on October 11th, 1933, with abdominal swelling and pain of six weeks' duration and eleven weeks' amenorrhoea. A diagnosis of fibromyoma was made, and a panhysterectomy was performed. The uterus showed a large intramural fibroid and a ten-weeks pregnancy. The patient developed peritonitis and died on the fourth day. All contacts were swabbed, including the pathologist who had been in the theatre during the operation but had failed to wear a mask; all other attendants were masked. Positive swabs were obtained from the following sources: Mrs. M. (peritoneum), Strain A; pathologist (throat), Strain B; anaesthetist (throat), Strain C; theatre sister (throat), Strain D; theatre nurse (throat), Strain E; theatre probationer (throat), Strain F; ward probationer (throat), Strain G.

Agglutination-absorption tests showed that strains A, B, and F were identical. None of the contacts took a manual part in the preparation of materials, the operation itself, or the after-care of the patient. The probationer wore a mask throughout. It would seem improbable that she was responsible. The evidence points to a direct droplet infection during the operation from the throat of the pathologist, who was previously unaware of being a throat carrier.

Mechanical Factors in Droplet Infection

In trying to determine the principles of the mechanics of droplet spray it was impossible to obtain standard conditions by asking carriers to cough or breathe at exposed culture material. Accordingly an apparatus was devised consisting of a painted plaster cast of a face,

through which were bored three holes representing the nares and a partly open mouth. Into the back of the cast was fitted the wide end of a funnel, the narrow end being joined to an atomizer spray charged with a broth culture of *M. Lyso-deiکتicus*. This organism is innocuous, and its colonies are easily recognized by their solubility in human tears (Fleming and Allison, 1927). Another advantage was that in testing materials for masking, the latter could be tied to the plaster cast in the same way as they are worn in actual practice. The apparatus, together with indications of planes along which culture plates were exposed, is shown on Fig. 1.

In the first series of experiments nutrient agar plates were exposed vertically at right angles to the lines AB, XY, CD, and EF, at varying distances from the mouthpiece. After counting the colonies developing on the plates, it appears that little spray passed upwards; most of the droplets fell rapidly, with the greatest concentration from ten to twenty inches from the mouthpiece. Very few droplets passed obliquely. In all subsequent tests plates were therefore exposed horizontally along the line CD. The results of a typical test with plates exposed along

GRAPH A.—Showing seasonal variations in percentages of haemolytic streptococcal throat carriers and percentages of cases of haemolytic streptococcal infection of the cervix.

GRAPH B.—Showing percentage incidence of haemolytic streptococcal infection of the cervix among those patients with haemolytic streptococci in their throats.

this line are shown in Graph C. At two distances, one a few inches and the other about fifteen inches from the mouthpiece, the concentration of droplets is high. There appear to be two types of droplets—one of low and one of high momentum.

Since momentum is a function of mass and velocity, the presence of these two groupings could be explained by either two sets of droplets, one of large and one of

small mass, or by one of high and one of low velocity. Investigating this point, both nostrils were blocked, spraying being performed through the mouth only. In Graph C it will be seen that by these means only the "long-distance" effect is obtained. Conversely, with the mouth blocked and spraying through the nostrils, the same long-distance effect was obtained. It would appear that the double grouping obtained with nares and mouth patent is due to the convergence of the buccal and nasal streams, wherein by collision some of the droplets lose their velocity and form a stream of low-momentum droplets.

Can these results be applied to spraying from the human nose and throat? A particle projected horizontally has two components of velocity—a horizontal velocity and a vertical—the latter a function of the force of gravity and the air resistance. Considering the vertical velocity—constant for all droplets with a constant depth—all droplets will reach the base-line at the same time. Considering the horizontal velocity, whatever the variations may be within the small range possible between that produced by the human cough or breath and that by the atomizer, owing to the retarding effect of air resistance—relatively great when compared with the initial velocities—the droplets rapidly attain the same horizontal velocity. After this the distance travelled is a function of that velocity and the constant vertical velocity. It appears, therefore, that the above work on the study of droplet projection applies to the study of droplet spray from the human nose and throat.

In practice, therefore, genital infection of patients from the upper respiratory tracts of accoucheurs could be accomplished by either high- or low-momentum droplets.

Infection by the high-momentum stream would be by direct implantation on to the vaginal introitus. The low-momentum stream would infect the front of the operator's gown and his sterile gloves, transference to the patient occurring at the next manual interference. Masks must be designed, therefore, to arrest both types of droplets.

Experiments with Masks

Similar spraying tests were performed through materials tied to the plaster cast. The materials used were varying numbers of layers of silk, surgical gauze, and fine dental gauze. Oblong masks, $6\frac{1}{2}$ inches by $4\frac{1}{2}$ inches, were prepared, with tapes at each corner to tie the mask securely across the nose and cheeks and beneath the chin. One to eight layers of each material were employed. Both streams of droplets were arrested by either two layers of silk, eight double layers of surgical gauze, or four layers of fine dental gauze. With

intermediate numbers of layers the amount of high-momentum spray was diminished, and there was a "shift to the left," as shown in Graph D. There was also a "shift to the left" of low-momentum droplets. The latter was not necessarily diminished, as is shown in the graph.

Thus the use of a mask of insufficient layers would be a menace, in that it would increase the amount of low-momentum droplets, with greater risk of contaminating the front of the operator's gown and gloves. In the above experiments masks have all been tied securely under the chin.

With masks hanging freely down, a large down-flow of droplets occurred, indicating that masks should be well secured below. Using oblong masks, an air gap is present at both sides. Plates exposed at the edge of the mask showed a side-flow of droplets, detectable for the distance of six inches from the edge of the mask.

To test the effect of prolonged use on their efficiency, two-layered masks of fine dental gauze were used; at every fifth stroke of the pump culture plates were exposed.

As the mask became more saturated it was rendered more efficient in arresting both types of droplets.

In reviewing the problems of masks it is clear that they should be of a sufficient number of layers of a suitable material to arrest both types of droplets, be designed to allow secure fastening under the chin, have a minimal air-gap at the sides, be comfortable to wear

FIG. 1.—Diagram of testing apparatus.

GRAPH C.—Showing number of colonies developing on plates exposed horizontally along line CD (see Fig. 1).

GRAPH D.—Showing number of colonies developing on plates exposed horizontally along line CD.

for long periods, and be easily sterilized. Two layers of silk and eight double layers of surgical gauze form mechanically efficient masks, but fall short on the other counts. Trials have therefore been made with various patterns of four-layered fine dental gauze masks.

A mask of the following design, adopted for use in the Jessop Hospital, consists of an upper and lower part; where the two join, the corners are mitred to form a "snout." This has rendered the mask less oppressive than the oblong mask; it fits snugly at both sides and beneath the chin. Masks of this pattern have been made by Messrs. Robinson and Sons, Ltd., Chesterfield, to whom thanks are due for their unfailing patience in preparing many types before the final pattern evolved. (See Fig. 2.)

FIG. 2.—Specification for face masks. The material for the fine dental gauze face masks must contain fifty warp threads and forty-four weft threads per inch square of the bleached gauze, and weigh 600 grains per square yard.

Discussion and Conclusions

Haemolytic streptococci are undoubtedly responsible for a large part of puerperal morbidity. There appear to be several modes of infection. It may be carried by the hands of accoucheurs, by direct spraying from the nose or throat of attendants, or by the patient's own hands. Hand transference by the obstetric attendant occurs in four ways: by carriage of septic material from some other case; by the hands being the site of some trivial lesion, unsuspectedly harbouring haemolytic streptococci; by the hands having been soiled from the pocket handkerchief by haemolytic streptococci; and, finally, by his hands having been infected by low-momentum droplets from his own throat. The precautions necessary to overcome such external contamination are the use of suitable masks and the adherence to a rigid technique of hand toilet (Colebrook). It must be strongly emphasized that masking should be done before anything else—hand toilet, setting out of instruments, etc.—is commenced.

In some centres where masks are not used puerperal infection is uncommon. This would suggest that masks are of little value; but in some of these centres a rigid system of hand toilet is practised rigorously before every vaginal examination, etc., is made, thus dealing with hand contamination by low-momentum droplets. Their success depends upon the prevailing discipline. Where this cannot be guaranteed, masking as the first step in the aseptic toilet should be practised.

For institutions the value of bacteriological control cannot be overrated. Patients known to be throat carriers should be warned of the danger of hand transference. In cases of heavy upper respiratory tract infection the patient's hands should be treated with antiseptics. In addition, if every midwife and every maternity centre were supplied with a notice embodying simple details of a standardized technique, a marked diminution in the morbidity might be expected.

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A CONCENTRATED LIVER EXTRACT FOR PARENTERAL ADMINISTRATION IN PERNICIOUS ANAEMIA

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Since the demonstration by Minot and Murphy of the efficacy of liver in the treatment of pernicious anaemia, the active principle has been produced in concentrated extracts, although efforts to isolate the haemopoietic substance have so far not been very successful. The earlier extracts admittedly obviated the necessity of ingesting large quantities of liver, but their potency was unreliable, and many could be scarcely called palatable. These difficulties were eventually overcome, but the extracts were expensive. The subsequent discovery that dried stomach was effective by mouth was an important advance, but it still required the daily administration of preparations which were often unpleasant. Further, the question of absorption of the active principle of liver extracts from the gut was always in doubt in cases in which there was little response to treatment.

Another advance was the preparation of active extracts which could be administered parenterally, but here again the question of cost was a serious consideration for the patient, and the necessity of frequent injections a handicap. The extract (pernaemon forte) which we have used in the treatment of six patients with pernicious anaemia overcomes to a certain extent both of these disadvantages. The preparation is a protein-free aqueous extract of liver, 1 c.cm. being extracted from 25 grams of liver and equivalent in activity to thirty to one hundred times this weight of fresh liver by mouth. In the following case reports it will be seen that only one injection is necessary to bring about marked clinical improvement and to raise the blood count to the normal level, and that maintenance doses are required only at one- or two-monthly intervals.

Case Reports

I

The first case was that of a married woman aged 39 years. There was a history of three years' gradual onset of weakness, palpitations, and vomiting. She was diagnosed as a case