OBSERVATIONS ON THE TREATMENT
OF EMPYEMA IN CHILDREN *

BY

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It is with some misgiving that I open a discussion on the treatment of empyema in children, since it is perhaps doubtful whether a physician is qualified to pronounce judgment on a subject regarded by many as being essentially surgical. And yet surely empyema is a disease which should vitally concern both physician and surgeon and which, almost more than any other, demands a close liaison between the two. The belief has been stated that there is a wide field in medicine to-day for the operating physician, and if such a person were available on the staff of every large hospital it might well be that the treatment of empyema would be in relatively safer hands than it is at present. There is perhaps a tendency to-day for the unfortunate child with empyema to fall between the two stools of medicine and surgery and, while conservatism and radicalism grapple with each other for pride of place in the scheme of treatment, the resulting delay and indecision may not react very favourably on the patient.

When discussing a wide and somewhat controversial subject such as this it would seem advisable, so far as is possible, to avoid mention of personal preference or impressions regarding treatment, since these are apt so readily to assume the guise of personal prejudice, which can only tend to complicate and distort the issue. I propose, therefore, to present a general review of the treatment of empyema as practised in the Royal Edinburgh Hospital for Sick Children during the past fifteen years. By this means it is hoped to obtain a reasonably detached and unbiased view of the situation and to assess the relative merits of the several methods of treatment. Before proceeding to details of these methods it is necessary to introduce an explanatory note to the effect that each type of procedure to be described was adopted by choice and not by expediency. To appreciate this is of importance, since it is common experience that children with empyema are sometimes admitted to hospital in such a low state of vitality that only the most conservative measures dare be employed, and even the minimum of intervention may be attended with grave risk. These emergency cases constitute a separate problem, and are not included in the sections concerned with the various methods of treatment, although brief reference is made to them in a later section.

During the fifteen-year period 1923 to 1937, inclusive, 363 cases of empyema were received into the wards of the Royal Edinburgh Hospital for Sick Children. Fifteen arrived *in extremis* and died within forty-eight hours; these have been omitted, since they were almost certainly beyond the reach of any form of treatment. The series under discussion therefore comprises 348 cases, and the various methods of treatment adopted will now be considered. In the first place, procedures which may be classed as conservative will be briefly discussed and certain of the more radical measures then considered.

Conservative Treatment

- REPEATED ASPIRATION

Drainage of the empyema by means of aspiration of pus from the thorax at frequent intervals was the procedure of choice in sixty cases, or 17.2 per cent. of the total series. As might be expected, this conservative method was favoured in very young children, one-half of those treated in this manner being under 2 years of age. The most successful results were obtained where the empyema was small in amount, and in six cases a single paracentesis sufficed to drain the cavity completely. Where the effusion was large this mode of treatment could not be regarded as very satisfactory, since the mortality was high and, in the cases which did eventually recover, the period of convalescence was often both long and difficult. The average length of stay in hospital after the development of empyema in these cases was 8.8 weeks. In three of those who survived, open operation had to be resorted to in the end in order to obtain adequate drainage, and it is at least a possibility that the fatalities would have been fewer if similar measures had been adopted with greater frequency and at an earlier stage in the illness.

TABLE I.—Showing the Results of Treatment by Repeated Aspiration

Age	Cases	Recoveries	Deaths	Mortality per cent.
Under 2 years ..	30	10	20	66.6
2-5 years	22	19	3	13.6
5-12 years	8	8	0	Nil
Totals	60	37	23	38.3

In this, as in subsequent tables, the cases have been divided into three age groups, and the very striking variation in the mortality rate according to age will be noted. The large number of fatalities which occurred during the period of infancy in this group is somewhat disquieting, since the simple procedure of aspiration is apt to be the method of choice in infants and very young children on account of its comparative safety. It would seem that in large effusions free and thorough drainage of the pleural sac is difficult to obtain by this method, and the resulting prolonged toxæmia may bring about a fatal issue before such drainage can be accomplished.

The infecting organisms isolated in this group were as follows:

Pneumococcus ..	55 cases	Streptococcus ..	1 case
Staphylococcus ..	3 "	<i>B. influenzae</i> ..	1 "

The various causes of death in the twenty-three fatal cases may be detailed thus:

Toxæmia	8 cases	Pericarditis ..	4 cases
Pneumococcal septicaemia ..	4 "	Spreading pneumonia ..	4 "
		Lung abscess ..	3 "

The causal organism in these fatal cases of empyema was the pneumococcus in twenty cases, the staphylococcus in two cases, and the *B. influenzae* in one case.

DRAINAGE BY CANNULA ASPIRATION

In fifty-two cases, or 14.9 per cent. of the total series, drainage of the empyema by means of a metal cannula was attempted.

A short silver cannula was inserted between the ribs into the pleural cavity and retained in position by means of gauze soaked in collodion, after the manner described by McNeil (1930). A rubber tube was then attached to the mouth of the cannula and clipped, and a thick pad of wool applied as a dressing. By means of a syringe attached to the tube, pus

* Read in opening a discussion in the Section of Diseases of Children at the Annual Meeting of the British Medical Association, Plymouth, 1938.

was aspirated through the cannula once or twice daily until the discharge became very scanty, whereupon the cannula was removed and the small sinus was allowed to drain openly. After each aspiration the usual practice was to inject into the cavity a small quantity of iodoform in liquid paraffin.

The results of this method of treatment, so far as actual mortality was concerned, were more satisfactory than treatment by repeated aspiration, but the extremely protracted convalescence associated with this procedure must detract from its success. The average length of stay in hospital from the commencement of the cannula drainage was 14.4 weeks, a figure which compares unfavourably with other methods of treatment. Furthermore, in nine cases cannula drainage proved inadequate, and after a long illness recourse to open operation became necessary to empty the cavity completely.

TABLE II.—*Showing the Results of Treatment by Cannula Aspiration*

Age	Cases	Recoveries	Deaths	Mortality per cent.
Under 2 years ..	21	13	8	38.1
2-5 years	20	16	4	20.0
5-12 years	11	11	0	Nil
Totals	52	40	12	23.0

It will be observed from Table II that cannula aspiration proved more successful in empyema of infancy than treatment by repeated aspiration, and on this account alone it is certainly worthy of consideration. The infecting organism was the pneumococcus in forty-nine cases of this group, the staphylococcus in two, and the streptococcus in one case respectively. The causes of death in those who failed to survive were as follows:

Toxaemia	7 cases	Spreading pneumonia	1 case
Pericarditis	2 ..	Scarlet fever	1 ..
Pneumococcal septicaemia	1 case		

Of the twelve fatal cases, the infection was due to the pneumococcus in eleven, the remaining case being one of streptococcal empyema.

DRAINAGE BY CLOSED SUCTION

This type of drainage was employed in only fourteen cases of the series, and it is therefore difficult to assess its true value in the scheme of treatment. For the sake of completeness, however, it is advisable that reference should be made to it. The technique usually consisted in making a small intercostal incision through which a rubber drainage tube was thrust into the pleural cavity. Suction was then applied to the tube by means of a Politzer bag or Bunsen bottles, the bag being favoured in the majority of cases.

Unfortunately it cannot be claimed that the results of this method of closed suction drainage were encouraging, although, as previously stated, the number of cases in which it was employed was too small to allow of any definite conclusion being reached regarding its efficacy. As was the case with other types of conservative treatment, the main difficulty was the maintaining of adequate drainage for a period long enough to ensure thorough emptying of the cavity, and in two instances open operation was ultimately required owing to the closed suction having proved quite inadequate to influence the size of the effusion seriously. Of the fourteen cases belonging to this group the infection was due to the pneumococcus in ten, the staphylococcus in three, and the streptococcus in one case. The results obtained are shown in Table III.

TABLE III.—*Showing the Results of Treatment by Closed Suction Drainage*

Age	Cases	Recoveries	Deaths	Mortality per cent.
Under 2 years ..	3	0	3	100.0
2-5 years	7	6	1	14.3
5-12 years	4	4	0	Nil
Totals	14	10	4	28.6

The average length of stay in hospital of the cases treated by closed suction drainage was 8.7 weeks from the beginning of treatment of the empyema. Of those who failed to survive, the cause of death was stated to be spreading pneumonia (two cases) and pneumococcal septicaemia (two cases).

Radical Treatment

Reference will now be made to those cases of empyema which were subjected to a more radical form of pleural drainage than has so far been described. In this group open operation was performed in every instance, the adherents of this regime being of the opinion that only by such heroic measures will free and adequate drainage of the pleural cavity be assured in children with empyema. When considering this group of cases it is important to bear in mind one significant fact—namely, that operation was never undertaken wittingly during the synpneumonic phase of the illness. If the diagnosis of empyema was made in the early stages, aspiration of the thorax was repeated until the pus became thick and localized, and immediate operation on admission to hospital was only performed when the history indicated that the disease was of long standing and exploratory puncture yielded thick pus. In the large majority of cases treated by open operation resection of a portion of rib was considered desirable, but in a small proportion open drainage was attempted without resorting to rib resection, and it will perhaps be of interest to consider these latter cases separately.

THORACOTOMY AND OPEN DRAINAGE

This method consisted in making a free incision in the intercostal space, incising the pleura, and, in some cases, aiding the evacuation of the pus and fibrin clots by means of a suction apparatus. Thereafter, a rubber drainage tube was inserted in the opening, and the cavity was allowed to drain on to the surface without suction. The results obtained in the thirty-seven cases in which this mode of treatment was employed are summarized in Table IV.

TABLE IV.—*Showing the Results of Treatment by Thoracotomy and Open Drainage*

Age	Cases	Recoveries	Deaths	Mortality per cent.
Under 2 years ..	7	1	6	85.7
2-5 years	20	16	4	20.0
5-12 years	10	9	1	10.0
Totals	37	26	11	29.7

It will be noted that the effects of this procedure in empyema of infancy were somewhat disastrous, since only one of the cases at this early age survived. The major difficulty associated with this method was the maintenance of free drainage from the pleural cavity, since the space available between the ribs was rarely found to be

of sufficient width to allow of the insertion and retention of a wide-bore tube. This difficulty, most pronounced in infants and very young children, was largely responsible for this mode of treatment being abandoned as unsatisfactory, and it is now never used in any circumstances.

The average length of stay in hospital following operation in this group was 8.2 weeks, and in the eleven patients who failed to survive the causes of death were as follows:

Toxaemia	7 cases
Pneumococcal septicaemia	2 "
Spreading pneumonia	2 "

The infecting organism was the pneumococcus in thirty-three and the streptococcus in the remaining four cases. The organism isolated in all the fatal cases was the pneumococcus.

DRAINAGE BY RESECTION OF RIB

Rib resection was performed in 185 cases of the series, which represents 53.2 per cent. of the total. Two distinct varieties of post-operative drainage were employed, according to the preference of the individual surgeon, and it will perhaps be profitable to consider each of these procedures separately.

(a) *Rib Resection with Closed Suction Drainage*.—This type of drainage was favoured in seventy-three cases, and consisted in careful closure of the operation wound round a rubber drainage tube, to which was applied a suction apparatus in the form of Bunsen bottles or a Politzer bag. Continuous closed suction was usually maintained in this manner for about one week following operation, and thereafter the sinus was allowed to drain openly. The results are summarized in Table V.

TABLE V.—*Showing the Results of Treatment by Rib Resection and Closed Suction Drainage*

Age	Cases	Recoveries	Deaths	Mortality per cent.
Under 2 years ..	11	8	3	27.3
2-5 years	38	34	4	10.5
5-12 years	24	23	1	4.2
Totals	73	65	8	11.0

It will be noted from these figures that the immediate results of treatment by rib resection and closed suction drainage compare favourably with the other methods of treatment already described. Furthermore, this procedure had the added advantage that convalescence was relatively short, the average duration of stay in hospital following operation being only five weeks. The infecting organism in these cases was the pneumococcus in sixty-seven, the streptococcus in three, and the staphylococcus in three.

The various causes of death in the eight patients who failed to survive in this group were as follows:

Toxaemia	4 cases	Pericarditis	1 case
Pneumococcal peritonitis	2 "	Pneumococcal septicaemia	1 "

The empyema was pneumococcal in origin in all the fatal cases.

(b) *Rib Resection with Open Drainage*.—Open drainage following rib resection was employed in 112 cases of empyema. The technique consisted in inserting a rubber tube or portion of a rubber dam into the operation wound and allowing the pus to drain on to the surface unaided by suction. The results obtained are detailed in Table VI.

TABLE VI.—*Showing the Results of Treatment by Rib Resection with Open Drainage*

Age	Cases	Recoveries	Deaths	Mortality per cent.
Under 2 years ..	17	13	4	23.5
2-5 years	58	50	8	13.8
5-12 years	37	36	1	2.7
Totals	112	99	13	11.6

Study of the above table reveals that this mode of drainage yielded results very similar to those obtained by rib resection with closed suction drainage, and it is probable that the slight variations in the mortality rates at the various ages are not in any way significant. The average duration of convalescence following operation was also very similar to that in the preceding group—namely, 5.5 weeks. The causal organism was found to be the pneumococcus in 102 cases, the streptococcus in six cases, and the staphylococcus in four cases.

The causes of death following rib resection and open drainage were as follows:

Toxaemia	4 cases	Pericarditis	1 case
Pneumococcal septicaemia	4 "	Intrathoracic haemorrhage	1 "
Peritonitis	2 "	Dysentery	1 "

The pneumococcus was isolated in twelve of the fatal cases, and in the remaining case the infection was due to the streptococcus.

Conservative and Radical Measures Compared

The more important methods which are regularly practised in the treatment of empyema in children have been considered individually, and it may be instructive at this juncture to view the subject from a wider angle. For this purpose it is proposed to group the various procedures adopted under two main headings—namely, conservative and radical—since the choice between these two types of treatment would seem to be the major point at issue in the management of the child with empyema. Under the heading of "conservative treatment" are included those cases treated by repeated aspiration, cannula aspiration, and closed suction, whereas "radical treatment" includes thoracotomy with open drainage and rib resection.

In Table VII the results of these two forms of treatment are compared at each age group, since it has been clearly shown that the success or failure of any procedure which may be adopted in empyema is determined to a great extent by the age of the child.

TABLE VII.—*Contrasting the Results of Conservative and Radical Treatment*

Age	Conservative		Radical	
	Cases	Mortality per cent.	Cases	Mortality per cent.
Under 2 years ..	54	57.4	35	37.1
2-5 years	49	16.3	116	13.8
5-12 years	23	Nil	71	4.2
Totals	126	30.9	222	14.9

This comparison of results is of interest, since the figures indicate quite clearly that in this series of cases radical measures proved more successful than conservative in infancy and early childhood, and the general mortality resulting from conservative measures was approximately double that which occurred in the operation cases.

Considerable divergence of opinion is found in the literature on this subject.

Michalowicz (1935) found that conservative treatment of empyema was attended with a lower mortality than operation at all ages, whereas Steinke (1935) concluded that rib resection gave a lower mortality than any other form of treatment. Brown (1923) reported that his mortality rate with rib resection was 21.5 per cent., as compared with a mortality of 40.3 per cent. in cases treated by intercostal drainage. Rienhoff and Davison (1928) believe that in infants under 2 years of age rib resection and open drainage will yield the best results, and express the opinion that the younger the patient and the poorer his condition the more important it is to establish free drainage.

To facilitate comparison with figures concerning the mortality at various ages published from other centres Table VIII has been prepared. This shows the number

TABLE VIII.—Showing Mortality according to Age for the Total Series

Age	Cases	Recoveries	Deaths	Mortality per cent.
Under 2 years ..	103	45	58	56.3
2-5 years	165	141	24	14.5
5-12 years	95	91	4	4.2
Totals	363	277	*86	23.7

* 15 of these patients died within forty-eight hours of admission to hospital.

of deaths and the mortality rate at the three age groups for the total series, irrespective of the mode of treatment. In this table are included, for the sake of completeness, fifteen patients who were admitted to hospital *in extremis* and who died within forty-eight hours of admission. As previously stated, these cases have been omitted from the foregoing sections dealing with the treatment of empyema because their precarious condition precluded any serious attempt being made to drain the pleural cavity. In fact, in eight of these cases the diagnosis of empyema was not established until necropsy.

Commentary

When an attempt is made to assess the relative merits of different forms of treatment in any disease pitfalls are apt to be encountered which certainly do not facilitate reliable conclusions being reached. In such a condition as empyema in children, where several factors may complicate the issue in each individual case, the temptation is great to eschew all dogmatism concerning treatment and to fall back on the vague generality that every case must be treated on its own merits. An attitude such as this may be safe, but it is singularly negative and unhelpful, and the purpose of this investigation was to discover, if possible, a definite answer to the question, What is the most satisfactory method of treating empyema in children? It is almost certainly true to say that the ideal treatment of empyema has not as yet been evolved, and that no finality has been reached regarding this important problem. Nevertheless, it is desirable that methods in common use to-day should be reviewed from time to time, thus enabling us to take stock of the situation and clarify our outlook.

A discussion on the treatment of empyema in children based on the study of a fairly large series of cases over a period of years is open to certain objections, but it is probably the best means at our disposal of obtaining reliable evidence. In this study it has been possible to contrast different forms of treatment, and although it would be unwise to draw any rigid conclusions, certain

points which arise from this investigation are perhaps worthy of note. The fundamental choice that has to be made regarding the treatment of a child with empyema must lie between conservative measures on the one hand and radical or surgical measures on the other, and the trend in some centres to-day would appear to be towards the conservative treatment of empyema because of its supposed freedom from risk as compared with more drastic operative procedures. It will be evident that the findings in this investigation do not lend support to such an attitude, but rather suggest that the most successful treatment of empyema in children of all ages consists in free drainage of the pleural cavity by means of rib resection. As has been indicated, recovery will occur with such measures as repeated aspiration and cannula aspiration alone, but it will not occur so frequently and so rapidly, and there is always the possible contingency that after enduring a long and exhausting illness the child will, in the end, have to face the added ordeal of operation. It is now generally accepted that before the operation of rib resection is undertaken in empyema the child must be suitably prepared and, except in chronic cases, preliminary localization of the effusion by means of aspiration is of vital importance. Thus a skilful blending of conservative and radical procedures, the one being complementary to the other, would appear to be the method of choice at the present time, provided that operation is performed at the earliest moment compatible with safety. The mode of drainage following rib resection does not appear to be of serious import, although the evidence awards a slight advantage to closed suction.

In the foregoing pages I have dealt only with the immediate results of treatment of empyema in children, since it has not been possible to obtain a sufficiency of reliable data regarding such important details as lung expansion and time of complete closure of the sinus. Such evidence as is available, however, seems to indicate that the later effects of rib resection in children will bear comparison with any of the alternative procedures described.

To conclude, it may be stated that ultimate rib resection with free drainage of the pleural cavity would seem to be the safest and most expeditious means of treating empyema in children of all ages. Conservative measures, such as repeated aspiration of the thorax, are of great value as a preliminary to radical operation, but, except where the pus is very small in amount, to attempt a cure by these measures alone is merely to prolong the illness unnecessarily, and may even endanger life.

Summary

A review is presented of the several types of treatment employed in a series of cases of empyema in children occurring during a period of fifteen years. It is revealed that the success or failure of any form of treatment is governed to a large extent by the age of the child, the mortality reaching a very high level during infancy.

The immediate effects of treatment by purely conservative measures are discussed, and these are contrasted with the results obtained by more radical procedures. It is apparent that, in those relatively few cases where the pus is very small in amount, cure can be effected without risk by conservative measures alone.

In this series of cases the most successful method of treatment proved to be the operation of rib resection, performed immediately after localization of the empyema had been achieved by means of repeated aspiration. The mortality following this procedure was only 11.4 per cent., a figure which compares very favourably with that of

other forms of treatment. Furthermore, the period of convalescence was found to be relatively short.

The manner of drainage following rib resection did not appear to have any significant influence on the mortality, since a striking similarity was observed in the immediate effects of both closed suction and open drainage.

The causal organism was proved to be the pneumococcus in 90 per cent. of the cases in the series, the infection in the remainder being due either to the streptococcus or to the staphylococcus. The immediate results of treatment were not significantly influenced by the nature of the infecting organism.

I wish to record my thanks to the physicians and surgeons of the Royal Edinburgh Hospital for Sick Children for allowing me free access to their case records of empyema.

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SYNERGY IN EXPERIMENTAL CHEMOTHERAPY OF STAPHYLOCOCCAL INFECTIONS

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Since the observation of Tréfouël *et al.* (1935) that the therapeutic activity of the hydrochloride of 4-sulphonamido-2:4-diamino-azo-benzol is due to the parent compound *p*-aminobenzenesulphonamide itself, a considerable number of papers have been published referring to the use of this drug in the treatment of certain human infections of coccal origin in general and that caused by haemolytic streptococci in particular. But in spite of these extensive investigations very little work has yet been carried out on the efficacy of this newly discovered drug in staphylococcal infection. Of the literature which has special reference to its use in such infection the observations of Troisier *et al.* (1937) and Thiers *et al.* (1937), as well as that of Frank (1937), need only be mentioned. The latter is again significant from the fact that the drug used was *p*-aminobenzenesulphonamide. A knowledge of the protective action of this drug against staphylococcal infections seems now to be of considerable interest, as this coccus is also responsible for the development of virulent toxin in human beings.

Accordingly a *Staphylococcus aureus* (local) strain was chosen and its toxicity was first ascertained. The strain after eighteen hours' culture in broth was noticed to be lethal within twelve hours of infection for white mice, weighing from 10 to 12 grammes (the type of animals used for subsequent experiments), in doses varying from 0.1 to 0.15 c.cm. (each cubic centimetre containing about 1,000 million organisms).

The Experiments

In a preliminary experiment nine mice were infected intraperitoneally with approximately five minimal lethal doses of the above strain. Six of the mice were given

within half an hour 7.5 mg. of *p*-aminobenzenesulphonamide in a sterile aqueous solution by the subcutaneous route. In order that no untoward symptoms might develop, as noticed in our previous experiments (De and Basu, 1937), a freshly prepared solution of the drug was always used. The remaining three mice received no treatment, and served as controls. The animals were then kept under observation, when all the latter animals were found to die within twenty-four hours, and only two of the former (treated) group survived after a period of seventy-two hours.

Thus the drug seems to possess no specific protective action, and consequently it was considered to be of importance to investigate the relative efficacy of *p*-aminobenzenesulphonamide and of a potent specific anti-staphylococcus serum. For this a staphylococcus antitoxic serum containing 600 international units per c.cm. and a sample of antibacterial serum were selected from the stock, and 50 units of the former and 0.5 c.cm. of the latter were injected into each animal after dilution with normal saline. Forty-eight mice of average weight—10 to 12 grammes—were taken and divided into four groups of twelve each.

Group A.—These were infected intraperitoneally with 0.5 c.cm. of broth culture of the above local strain. They received no treatment, and served as controls.

Group B.—Each of these animals was given intraperitoneally 50 units of antitoxic and 0.5 c.cm. of antibacterial serum, diluted with normal saline, and after half an hour was infected with 0.5 c.cm. of the broth culture.

Group C.—The animals were first treated with 3.5 mg. of *p*-aminobenzenesulphonamide in sterile aqueous solution; three hours later they were infected with 0.5 c.cm. of the culture, and 4 mg. of the drug was again administered after three hours of this infection.

Group D.—This group of animals were given a combination of the treatment used in Groups B and C. Thus each animal was injected with 3.5 mg. of the drug, and after two and a half hours 50 units of the antitoxic and 0.5 c.cm. of antibacterial serum diluted with normal saline were administered. Within half an hour it was infected with 0.5 c.cm. of the culture, and was again given 4 mg. of the sulphonamide after three hours of this infection.

All the animals were kept under observation over a period of ninety-six hours, and a post-mortem examination of those which died was made to find out the cause of death. The table below gives the results of these investigations.

	Hours				Necropsy and Blood Culture Report of the Dead Mice
	24	48	72	96	
Group A	All dead	—	—	—	<i>Staph. aureus</i>
Group B	8 Dead 4 Alive	1 Dead 3 Alive	3 Alive	3 Alive	"
Group C	2 Dead 10 Alive	4 Dead 6 Alive	2 Dead 4 Alive	— 4 Alive	"
Group D	All alive	All alive	All alive	All alive	—

Average weight of mice, 10 to 12 grammes. Nature of strain, *Staph. aureus* (local). Number of organisms, 1,000⁶ (18 hours' broth culture) per c.cm. Infection dose, 0.5 c.cm.

Next, to find out whether *p*-aminobenzenesulphonamide possesses any bacteriostatic action *in vitro* upon broth cultures of *Staph. aureus*, different amounts of the drug varying from 0.25 to 7.5 mg. were added to 10 c.cm. of the broth cultures and left in an incubator for eighteen hours. No inhibition of growth was noticed in any of