THE BRAGG-PAUL PULSATOR IN TREATMENT OF RESPIRATORY PARALYSIS*

REPORT ON THIRTY-FOUR CASES

BY

C. J. McSWEENEY, M.D., F.R.C.P.I., D.P.H.

Respiratory paralysis following diphtheria is a comparatively rare condition, but it is not uncommon when diphtheria of a virulent form is prevalent. Among roughly 3,000 cases of diphtheria treated in recent years thirty-three authentic instances of respiratory paralysis have occurred in Cork Street Hospital. In all cases the involvement of the diaphragm, with or without the intercostals, was part of a widespread post-diphtheritic paralysis. A pre-existing palatal and pharyngeal paralysis was invariable, and in a majority of cases some other paralysis was present as well—for example, ciliary, external rectus, neck muscles, facial muscles, etc. Most commonly the involvement of the respiratory muscles occurred at the end of the sixth or during the seventh week. The onset of the paralysis was most often gradual, but in a few instances sudden arrest of respiration occurred, with alarming symptoms of defective pulmonary aeration. Respiratory paralysis was met with only in those cases of severe nasopharyngeal diphtheria which, in the early stages of the disease, had "bull necks" and severe toxaemia. There were, however, three cases of "missed diphtheria" admitted to hospital, respectively on the fourteenth, thirty-first, and forty-second day of the disease, with post-diphtheritic paralysis, and in these cases one can only assume the extent of the throat lesions, which had cleared by the time the children were admitted to hospital. One other case of respiratory paralysis is included in this series, the cause here being a spreading anterior poliomyelitis.

The Apparatus

Since October, 1935, every case of respiratory paralysis has been treated in the Bragg-Paul pulsator—an apparatus designed by Mr. R. W. Paul at the suggestion of Sir William Bragg. The original apparatus was shown by me to the Dublin Biological Club in October, 1935, and was demonstrated by Dr. Kerridge of the Department of Physiology of the University of London at the Annual B.M.A. Meeting in Oxford in 1936. Briefly, the apparatus consists of a distensible rubber bag applied around the patient's chest in the form of a belt, this belt being rhythmically filled with, and emptied of, air from a bellows, which in turn is compressed and relaxed by a moving plate, operated electrically. There is a gauge to indicate the amount of pressure applied to the chest, and the rate of compression can be modified to suit the respiratory rate of the patient—18, 20, or 22 strokes per minute, as the case may be. The pressure in the chest belt is controlled by an escape-valve fixed to the bellows, and by opening this valve to a greater or less extent the pressure can be reduced or raised. With the original apparatus pressures of 0 to 25 mm. Hg give completely satisfactory results for children of 4 or 5 years of age, but the one adult patient treated required 10 to 35 mm. Hg.

Results of its Use

Up to date thirty-four cases have been treated in the apparatus, and of these twenty-six made uneventful recoveries. One of the eight fatalities had been treated in the apparatus for four days when the machine broke down, and before a new part could be made the patient died. The remaining seven patients died of causes other than respiratory failure—six of them from late cardiovascular failure, and one from gangrene a fortnight after coming out of the pulsator and sixty-one days from the onset of his diphtheria. Of the twenty-six cases treated successfully it will be sufficient perhaps to give one or two illustrative examples. All the cases conformed to this type, and to include others would be waste of time.

Illustrative Cases

Case No. 390/37.—A boy aged 6, with very toxic nasopharyngeal ("gravis") diphtheria and marked haemorrhagic extravasations into skin. Admitted on the fourth day; palatal paresis occurred on the eleventh, paralysis of the neck muscles on the twenty-fifth, pharyngeal paralysis on the thirty-first, and complete diaphragmatic paralysis on the thirty-eighth; put in pulsator. Full recovery of the diaphragm was very slow, and because of sluggish shallow respirations the pulsator was kept on until the fifty-sixth day, when the respiratory muscles were found to be completely recovered. All other paralysis cleared up about the same time, and subsequent recovery was uneventful.

Case No. 770/37.—A boy aged 5 with very toxic faucial diphtheria of the "gravis" type and considerable skin haemorrhages. Admitted on the alleged second day. Palatal paresis occurred on the seventh day, early cardiovascular failure on the eighth, with vomiting, precordial pain going on to gallop rhythm on the fifteenth, paralysis of the neck muscles on the twenty-fifth, pharyngeal paralysis on the thirty-sixth, and sudden arrest of respiratory muscles on the fortieth day; put in pulsator. There was ptosis of the left eyelid on the forty-second day and the respiratory muscles were functioning normally on the forty-fifth. The pulsator was now discontinued. Left internal strabismus was observed on the fifty-first day. The pharyngeal paralysis cleared up on the fifty-fourth, the neck muscles on the sixty-ninth, and the strabismus on the seventieth. Subsequent recovery was uneventful.

I ought to add that there was no interference with the routine management, nursing, and treatment of patients, all of whom were nasally fed for a coexistent pharyngeal paralysis while receiving artificial respiration. Most of the patients were quite young children, but none raised the slightest objection to treatment in the apparatus. They slept normally while undergoing artificial respiration, and the other occupants of the ward did not object to the operation of the pulsator. There can be no doubt that this simple but ingenious apparatus marks a great advance in the treatment of a sequel of diphtheria which has been hitherto almost invariably fatal. The patient with anterior poliomyelitis behaved in an exactly similar manner to the diphtheritic cases when put in the pulsator. On two occasions two children developed respiratory paralysis about the same time, and in this emergency the escape-valve was connected to another belt by means of a length of hose-pipe and suitable fittings, and by this makeshift arrangement we were able to maintain artificial respiration successfully in the second child without disturbing the one already under treatment. All four children eventually recovered.

The apparatus has also been employed at the Richmond Hospital, Dublin, and I am informed by Mr. A. McConnell, P.R.C.S.I., that recently it saved life by restarting respiration in at least two of his patients during the course of prolonged brain operations.

Improvements

During the last twelve months I have been in constant touch with the original designer of this apparatus, Mr. R. W. Paul, and have kept him advised as to certain minor troubles we have experienced with the pulsator. The chief

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of these was the sucking in of the bellows, with consequent chafing, necessitating frequent repair of punctures and eventually replacement of the bellows. Mr. Paul has entirely got over this difficulty by providing for a shorter length of stroke (2¾ inches instead of 3⅛ inches), and certain other modifications have also been incorporated to ensure almost noiseless working of the apparatus. One other improvement is the inclusion of a two-way connexion which readily allows two children to be treated in the apparatus simultaneously—a direct development of the improvised arrangement we made in Cork Street two years ago. Another important improvement in the belt is the addition of shoulder-straps, which will prevent the belt from slipping down over the abdomen, an eventuality that had to be constantly watched for with the older belts. The fastening of the new belt is by means of a chain clip, which is also an improvement on the older buckles.

Conclusion

The Bragg-Paul pulsator is an efficient artificial respirator which is specially adapted to the treatment of post-diphtheritic respiratory paralysis or respiratory paralysis due to anterior poliomyelitis. It is also of use in restarting respiration which may be reflexly stopped during the operation of tracheotomy or during any operation where such reflex stoppage may be anticipated. It has been used, too, to re-expand a lung and cause healing of a chronically discharging empyema. The new model is a more compact and a neater apparatus than the original, and promises to have even greater efficiency as an artificial respirator.

TRANSFUSION WITH STORED BLOOD

BY

T. I. WILSON, M.B., F.R.C.S.Ed.
Clinical Tutor, Royal Infirmary, Edinburgh

AND

J. M. M. JAMIESON, M.B., Ch.B.
Late House-Surgeon, Royal Infirmary, Edinburgh

Transfusion with stored blood has been practised for many years, and during the great war it was used particularly in the front-line hospitals of certain Dominion medical units. Thereafter the practice appears to have fallen into disuse, but was revived again more recently by Russian surgeons, who use blood taken from the cadaver within a few hours of death. It is also recorded that certain supplies of stored blood have proved of great value in the course of the present civil war in Spain.

This paper contains details of fourteen cases of blood transfusion exemplifying the value of having a supply of blood in cold storage, ready for immediate use. The field of investigation has been purely a clinical one, and our observations have been limited to the general reaction of the patient to the treatment carried out. The indications for transfusion, in the cases here recorded, were, for the most part, weakness and anaemia associated with sepsis and malignant disease rather than the replacement of blood loss by haemorrhage, which was present in only three instances.

The Source of Supply

The source of supply has varied; two patients with polycythaemia were generous donors, and in the other cases the blood was obtained from healthy individuals. In all except one case the blood was Group IV in type, and in each instance the citrate method was employed, the concentration of sodium citrate being 0.38 per cent. in the stored blood.

Technique

The blood is withdrawn from the donor's cubital veins under strict aseptic conditions, and is collected in sterilized flasks containing the required amount of sodium citrate solution for the quantity of blood withdrawn. A pint of blood is thus collected in each flask, which is closed with a sterile plug of gauze and wool, and then sealed and labelled. This supply is stored at once in a refrigerator at a temperature of $-10°$ to $-3°$ C. In our series of cases the stored blood has been used after a period of from four to thirty-eight days.

Serological tests are carried out upon all donors, and before use the patient's serum is typed directly against the corpuscles of the stored blood. On examining the stored blood microscopically, even as late as five weeks from the time when it was originally put on ice, the erythrocytes were observed to be normal in appearance in every way, except for a few which showed crenation. During storage, sedimentation of course occurs, and before use the flask is gently agitated to mix the cells again with the plasma. The method wherein sterile glass balls are placed in the flask to promote more thorough mixing we do not favour, as this tends to break down many of the cells.

After mixing the blood thoroughly, it is decanted into a sterile measure through a filter composed of layers of gauze. This filter is necessary, because late clotting tends to occur in citrated blood in certain cases, and clots must of course be eliminated. The blood is infused into the recipient's circulation, through a vein in the arm, by means of a funnel, tube, and glass cannula. It is given unheated, the reason being that heat would appear to cause an alteration, possibly of the protein content, and toxic symptoms may follow the administration of blood so treated. Our practice is to give the blood after it has stood at room temperature for a period of from half to one hour. The flask is then still cold to the touch. In the cases reported below only two were followed by a reaction, and in these the blood had been heated to "normal" temperature. It is significant in this connexion that we have observed reactions follow immediate transfusions in cases where the flask of blood has been placed in warm water.

The second precaution to be taken in administering the blood is to ensure that the rate of flow is even and slow. We endeavour to occupy a period of about fifty minutes in giving one pint of blood, this representing a quantity of just over 10 c.cm. per minute. This rate of flow is frequently diminished by spasm of the vessel induced by the cold blood.

Case Records

Case 1.—A man aged 49 suffering from carcinoma of the colon with peri-neoplastic abscess, was admitted with acute obstruction. Colostomy was performed and, later, resection. The first transfusion, one pint of Group IV blood five days old, was given on October 15, 1936, and a second transfusion, one pint of Group IV blood twenty-one days old, was administered on December 7. There were no reactions, and the patient is now alive and well.

Case 2.—A man aged 50 with carcinoma of the urinary bladder. The ureters were transplanted into the colon and total cystectomy was performed. The first transfusion, given on October 18, 1936, was one pint of Group IV blood eight days old; the second transfusion, on November 13, was half