paralysed. This is always in evidence if mechanical failures of respiratory apparatus develop or if the power fails. It can also be seen when using positive pressure through a face-mask when the tank has to be opened for the first time, and when weaning from respiratory aids is started. By learning frog breathing it might be said that the patient has taught himself to live and is no longer beset by fears of dying. After the initial psychological improvement due to removal of these fears further improvement develops through the sense of achievement from learning the technique and in acquiring further breathing-time. Other factors are the sense of freedom from respiratory aids and the ability to lead a fairly full social life. It is possible that some of the psychological improvement in our patient could be put down to the eventual acceptance of his position, but we feel that the dramatic coincidence with the ability to frog-breathe is against this.

Chronic respiratory cripples confined to an institution live a far more circumscribed life than can be imagined by normal people. They have little interest beyond the four walls of their ward and at times show a remarkable ability to be petty and "take it out" of their attendants. Jealousies of attention given to other patients become a prominent feature of their reaction to their environment. This hostility reaction is, of course, not uncommon in many disabling diseases. It is of greatest importance to enlarge the small unchanging scene before them. In patients "fixed" to a ward, social interests are confined to daily visits by friends and relatives, to routine talks, to cinema shows, and to occupational therapy. However, the main drawback to this existence is that they themselves are static, and it must be obvious to them that their own interests are due to artificial stimuli, dependent upon others. On the other hand, a patient who is independent of fixed respiratory aids becomes able to enjoy an ever-changing source of stimulation from outings in a wheelchair, car rides, etc. He now feels that although he is physically unable to move he is no longer utterly dependent upon the visitations of others to obtain the stimuli necessary for normal expression.

Before learning G.P.B. our patient had frequent fits of depression with episodes of weeping several times a day. He was difficult to amuse, because his interests flitted from one thing to another. He had evidence of withdrawal, and as a rule did not encourage visitors other than his close family circle. He was thin, ate indifferently, and always had pains here and there. Since mastering the technique the weeping fits are a thing of the past. He spends considerable time reading, typing with a mouth-stick, and playing chess, and doing jigsaw puzzles, also with a mouth-stick. He is much less hostile and does not try to put "a spanner in the works," except very occasionally. He is now pleased to see any visitors who might wish to see him. He eats well, rarely complains, and is plump and sunburnt.

G.P.B. has so many advantages that we believe that the teaching of this technique is one of the most important advances made in the treatment of respiratory poliomyelitis in recent years.

Summary

A description of the mechanism of glossopharyngeal breathing is given. The disadvantages are briefly outlined and a description of some of the physical and psychological advantages is given.

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SPIROGRAPHIC STUDIES IN GLOSSOPHARYNGEAL BREATHING

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Glossopharyngeal breathing (G.P.B.) has been used in the U.S.A. and in Scandinavia as a substitute for the normal respiratory mechanism in patients with gross paralysis of the respiratory muscles and to augment the remaining ventilatory ability. It may also be used to improve the compliance of the lungs and chest and to aid the coughing power.

This investigation was carried out to estimate the speed of air flow during expiration, which is important in coughing; to estimate the effect of different positions on the efficacy of the method; and to attempt to elucidate the peculiar characteristic features of the spirographic pattern.

The subject of these tests was an 18-year-old European male who had complete paralysis of all spinal muscles except those of his neck and the right upper rectus abdominis. He had been taught to use G.P.B. after he had been paralysed for nine months. The tests were performed over a period of 10 months, beginning some six weeks after he had learned G.P.B.

During the period of observation there was no improvement in the degree of paralysis, the vital capacity remaining at 200 ml. throughout this time.

Methods

Spirographs were obtained, using (1) the Sandborn metabulator or a Benedict-Roth spirometer at slow speeds, and (2) a high-speed kymograph (20 cm. in 10 seconds) with a spirometer similar to that described by Bernstein *et al.* (1952). Recordings were made in the semi-sitting and in the supine position both during spontaneous respiration and during G.P.B.

During the tests the patient held the mouthpiece between his teeth, the nose being clipped. The spirometers were filled with a mixture of approximately 50% air and 50% oxygen.

All the results are at ambient pressure and temperature, and saturated. The average atmospheric pressure was 625 mm. Hg and the temperature 23–25° C.

Measurements were made of the minute-volume, the vital capacity, the number of strokes per breath, the number of breaths per minute, and the speed of each stroke. The

Results

	Spontaneous Respiration	Glossopharyngeal Breathing
Vital capacity	200 ml.	{ Supine, 2,464 ml. Semi-sitting, 2,016 ml.
Maximum expiratory flow	Over 100 ml.— 15 l./min.	Over 1 litre: (a) Normal G.P.B., 86 l./min. (b) Maximum G.P.B. effort: Sitting, 109 l./min. Supine, 85.7 "
Stroke volume		60 ml. approx.
" duration		Variable: 0.40–0.55 sec.
No. of strokes per breath		10–12
Respiratory rate	24/min.	6–8/min.
Tidal volume	200 ml.	600–660 ml.
Minute-volume	4,800 "	4,800–5,200 ml.

All volumes are at ambient temperature and pressure saturated.

speed of maximum expiratory air flow was measured during expiration following a "normal" glossopharyngeal breath and following a maximum glossopharyngeal effort.

The results are given in the accompanying Table.

Discussion

Pattern of the Spirograph.—The presence of a mouth-piece and of a nose-clip and the resistance of the spirometer interfered to some extent, and the figures shown therefore probably do not represent the true performance. Previous spirographic recordings of G.P.B. on a Sandborn metabulator (Dail *et al.*, 1955; Zumwalt *et al.*, 1956) show

the same pattern as did ours as illustrated in Fig. 1. The characteristic pattern appears to be a comparatively large initial inspiration followed by smaller saw-tooth inspirations.

The fast recording kymograph (Fig. 2) brings out in detail his characteristic saw-tooth effect. It is possible that the expiratory part of the saw-tooth is caused by the expulsion of a small part of the air trapped in the mouth when the piston action of the tongue takes place at the beginning of the inspiratory

FIG. 1.—Spirogram of G.P.B. in the supine position showing, from left to right, "normal" G.P.B., a maximum G.P.B., and spontaneous respiration.

FIG. 2.—High-speed spirogram (20 cm. per sec.) showing the characteristic pattern of G.P.B.

gulp. A thread held in front of the mouth during G.P.B. shows that some air is expelled just before the lips are closed.

Vital Capacity.—The predicted vital capacity for the patient—height 5 ft. 10 in. (178 cm.), weight 130 lb. (59 kg.)—based on West's (1920) normal values, is approximately 4,350 ml. The patient's vital capacity when breathing spontaneously is less than 5% of this. If the maximum glossopharyngeal effort can be compared with the vital capacity, then G.P.B. in the supine position increases the figure to more than 50% of the predicted normal. In normal subjects the vital capacity is greater when sitting than when recumbent. In our patient the glossopharyngeal "vital capacity" in the supine position was some 400 ml. more than in the semi-sitting position. We feel that this apparent paradox is explained by the fact that in these

respiratory cripples only the inspiratory fraction of the vital capacity is present, as can be seen from Fig. 1. The inspiratory capacity in normal people is reduced when the position is changed from sitting to lying. Whitfield *et al.* (1950) found this reduction to be some 319 ml. in normal adults. The patient's explanation was that "his abdomen got in the way" in the semi-sitting position. Kaltreider *et al.* (1938), examining 50 normal males aged 18–30, found an inspiratory capacity ranging from 2,410 to 4,930 ml., with a mean of 3,790 ml., at 37° C. saturated in the recumbent position. The figures given by our patient would suggest that G.P.B. had almost restored the patient's inspiratory capacity to normal.

Maximum Expiratory Flow.—During spontaneous respiration the maximum expiratory flow could be measured only over 100 ml., but this flow was much less than the expiratory flow rate during a normal respiration, and was only 3.75% of the mean maximum expiratory flow of a normal adult. This serves to illustrate the handicap from which these patients suffer during coughing. During G.P.B. the maximum expiratory flow improved considerably—that is, 109 l./min. in the sitting position—though this is much less than the normal (400 l./min.). As the effectiveness of a cough is partially dependent upon the maximum expiratory flow the advantage of a respiratory cripple's ability to perform G.P.B. is evident. The maximum expiratory flow was greater when sitting. The vital capacity, as had been noted, was reduced in this position.

Stroke Volume and Duration of Stroke.—Dail *et al.* (1955) suggest that G.P.B. requires a stroke of volume of at least 1% of the predicted vital capacity and that the efficacy of this method is increased when less time is taken to complete each stroke. The time for each stroke in their patients was in the range 0.3 to 1 second. The stroke volume for our patient was 1.38% of the predicted vital capacity, each stroke being accomplished within a period varying from 0.4 to 0.55 second.

Tidal Volume, Minute-Volume, and Respiratory Rate.—Our patient is unable to breathe spontaneously for more than a few minutes at a time. The ventilation required during spontaneous respiration calculated from the Radford nomogram (Radford *et al.*, 1954) at this altitude (5,260 ft.—1,585 m.) at a respiratory rate of 24 would be 8,232 ml./min.; as can be seen from the Table, he is unable to do much more than 50% of this. At respiratory rates of 6 and 8 the required minute-volumes are 5,100 ml. and 5,880 ml. respectively. During G.P.B. he can provide himself with minute-volumes of approximately 4,800 to 5,200 ml. at these slower respiratory rates. The lower figures recorded by us might partly be due to the increased resistance of the mouthpiece and of the spirometer, coupled with the fact that the patient normally performs G.P.B. through his nose and mouth, whereas during the recordings he was able to breathe only through his mouth. This improvement of ventilation is amplified by the fact that he can breathe without an aid for some six hours at a time and has travelled by car for short periods at altitudes of 6,400 ft. (1,950 m.).

Summary

Spirographic recordings of glossopharyngeal breathing on slow and fast recording kymographs are presented. The improvement of the vital capacity and of the maximum expiratory flow rate due to glossopharyngeal breathing is demonstrated.

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