Muscle Breathing Patterns

Analysis With Respect to Various Combinations and Degrees of Muscle Weakness

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NEUROMUSCULAR conditions such as cerebral vascular accident, spinal cord injury, and poliomyelitis can cause impairment of the functions of daily living, travel, and occupation. The degree of such impairment depends on the severity and distribution of weakness, incoordination, limitation of movement, deformity, and lack of endurance and general body vitality.

Breathing—like the functions that have to do with the activities of daily living, travel, and occupation—is accomplished by contraction of skeletal musculature and consequently may also be impaired by neuromuscular diseases. Important as they are, functions other than breathing need not be maintained continuously, but breathing must be continuous from minute to minute, day and night, if life is to continue. Furthermore, adequate performance of all the activities of the body requires a good reserve of breathing capacity.

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The patient must have sufficient functional breathing reserve to meet the demands of his heaviest activity. Such a reserve is the arithmetic difference between the functional capacity of breathing and the demand placed on it. As with the other bodily activities, functional breathing capacity depends on the strength and the endurance of the respiratory muscles, the coordination of breathing movements, the mobility of the lungs, and structures of the rib cage and on the general vitality of the body. In addition to these factors, breathing is also influenced by the health of the lung tissue, the condition of the circulatory system, and the automaticity of the respiratory musculature as well as by the patency of the airway. The demand of the breathing function on the other hand, is roughly proportional to the muscular effort of the body and also varies in accordance with the level of breathing imposed by the respiratory center.

In some paralyzed cases, the lack of breathing reserve is not a problem even though functional breathing capacity is much impaired, for the muscular activity of the extremities and back are so involved that no more than very little increase in the breathing is ever demanded. On the other hand, some patients have so much remaining function in the muscles of the trunk and legs that they could easily walk were it not that the muscles of breathing are so weakened that metabolic activity cannot be met. Most of the problems of respiratory function lie between these two extremes.

It is the aim of rehabilitation to aid the patient in recovering all the bodily functions possible so that he will be a useful individual in society. In the very severely handicapped case, the aim would be to make him the least burden to society. In a patient with respiratory weakness, the aim would include building up maximal respiratory reserve function and, if possible, to free the patient from use of respiratory equipment. In such cases, it is evident, therefore, that careful evaluation of respiratory function is essential in order to facilitate the over-all rehabilitation program.

Evaluation of the patient should make use of all tools available. The most valuable of these include a history of the injury or disease, recognition of the patient's personal reaction to his treatment and rehabilitation programs, observation of the patient during rest and activity, and a physical examination. Although various respiratory measurements may be of value in the study of the case, they should not be depended upon exclusive of clinical judgment, and should be interpreted with caution. The patient should be evaluated during all the situations required of him by his program of rehabilitation. It is necessary to study him at rest and while active, in a reclining position and erect. He should be followed from day to day, and month to month.

Respiratory Measurements

Although the use of instruments of measurement is not the most important, it is still valuable and gives a numerical definition of the patient's function, and because of this aids much in following the progress of the case. Such measurements, however, may give an entirely erroneous picture of the patient's ability. In the evaluation of the respiratory muscle function, measurement is chiefly confined to the determination of the vital capacity and its component parts or compartments. I shall therefore discuss this as an aid in determining the patient's breathing reserve and as an introduction to the main thesis of this presentation.

When possible, vital capacity measurements should be taken with a suitable recording spirometer, such as a basal metabolism apparatus with low internal air resistance. By this means alone one may determine the resting end-expiratory position and measure the inspiratory capacity, the expiratory reserve volume, as well as the total vital capacity. Inspiratory capacity may be considered as a numerical expression of the integrated action of all the inspiratory muscles, and the expiratory reserve volume as a measure of the muscles of expiration. The tracing can also be analyzed for regularity, rate, and rhythm. Estimation of the coordination of breathing movements is thus aided. Since a permanent record is made, the progress of the case can be analyzed and documented.

Normally, vital capacity varies according to the body's size, age, and sex. With the aid of tables of normal vital capacity, the patient's vital capacity can be described in terms of percentage of normal.

Helpful as it may be, the vital capacity by itself may mean little in terms of breathing ability. This is illustrated in two cases. The first is that of a patient who is free of the respirator during the daytime and has been able to sleep free of respiratory aid for several nights on different occasions. His vital capacity is 17 per cent normal. The patient is up in his wheel chair from four to ten hours daily and participates in rehabilitation activities in the gymnasium. In contrast to this, another patient has a 15 per cent normal vital capacity, which is essentially the same. Her tolerance of being free of respiratory aid is only about two hours, and even at the end of that time she sometimes becomes quite exhausted. She is still confined to her bed.

Obviously it is necessary to recognize the other criteria already mentioned. This discussion will be limited to the physical examination and particularly examination of the muscle breathing patterns. The function of the component muscles that produce breathing should be analyzed in respect to strength, bodily activity and posture, relative efficiency and endurance, and their relative automaticity.

Muscle Breathing Patterns

Before a correct analysis can be made, the principles of normal muscular function and breathing must be well understood. In a normal subject lying supine and breathing quietly, the rhythmical movement is apparent. On inspiration, the chest expands actively. Simultaneously the abdomen expands. This is due to active diaphragm contraction. There is no neck accessory contraction. Expiration is a controlled relaxation of the inspiratory effort. The abdominal muscles are relaxed during both inspiration and expiration. At the end of expiration there is a momentary rest, which corresponds to the resting end-expiratory position on the respiratory tracing.

A common sequela of paralyzing diseases is chest muscle paralysis. This results in isolated diaphragm movement. Consequently, on inspiration the abdomen expands passively, due to the action of the diaphragm, as in the normal. The chest, however, does not expand. On the contrary, there may be passive retraction of the chest wall during inspiration, which may be considered paradoxical, or reverse breathing. During expiration there is a corresponding return of the movements.

Another pattern results from diaphragm paralysis. The remaining functional chest expands during each inspiration, but the abdomen retracts passively as the diaphragm is drawn passively upward into the chest. On expiration, the action is reversed. A rocking motion results, as the chest and abdomen alternately expand and retract. Isolated chest breathing causes another paradoxical or reverse breathing pattern. The phasing, however, is just opposite to that of the isolated diaphragm breathing.

Maximal deep breathing, even in the normal case, calls for accessory use of the neck muscles, as an aid in raising the chest cage by virtue of their attachment to the upper anterior portion of the chest cage. In extensive respiratory paralysis, the muscles of the neck may be the only ones retaining function. During inspiration, these muscles contract with obviously marked effort. Simultaneously, the neck extensor muscles and other supporting muscles must also tense, to stabilize the head.

Normally the active inspiration and passive expiration is followed by the resting end-respiratory position. However, more air can be forced out of the lungs beyond this resting position by forceful contraction of the abdominal and other expiratory muscles. The patient is thus breathing in the respiratory reserve compartment. Normally, this type of breathing is not called for, except when excessively deep breathing is necessary. In paralysis of the chest, diaphragm and neck muscles, however, breathing may be maintained for short periods of time by abdominal muscle contraction. This is active expiration, followed by passive inspiration. In such a case, the resting end-inspiratory position becomes the resting end-expiratory position.

Breathing Patterns and Artificial Respiration

Many patients with respiratory muscle weakness need artificial respiration, at least during the early period of paralysis. The returning function of breathing should be carefully considered during this period since an improper approach to the rehabilitation of respiratory muscle function may jeopardize maximal efficiency. It is therefore essential that the muscle breathing patterns should be examined in relation to artificial respiration.

There are essentially only three basic principles employed in the use of mechanical respiration: positive pressure breathing, head-to-foot rocking, and rhythmical abdominal compression.

Positive pressure breathing is the most commonly employed method and includes the use of the Drinker type of respirator, the cuirass respirator and intratracheal positive pressure. Both the chest and abdomen expand during inspiration, and there is a corresponding descent of the diaphragm. This pattern of movement is similar to that of normal quiet breathing, a fact that should be recognized in the retraining. Incoordination of the rhythm of the respirator with that of the patient may occur and should be avoided if at all possible. This can be observed as one compares what one would expect in passive artificial respiration using positive pressure with the patient's breathing rhythm. To furnish rest to the respiratory muscles is the object of the use of artificial respiration. In the presence of incoordination, however, the patient may actually become exhausted by the respirator.

Another principle is employed in the use of the rocking bed. When the foot of the patient's bed is tilted downward, the abdominal contents drop, thus causing the diaphragm to drop. There is an associated inspiration. Expiration occurs on reversal of the tilt. In contrast to positive pressure breathing, chest movement is not in accord with normal breathing, for the chest tends to retract during inspiration. The pattern simulates that of a case of chest paralysis. It has been our experience when patients use artificial respiration as an aid in respiratory retaining that positive pressure breathing is superior to rocking.

The third method of artificial respiration is also dependent upon gravity. This method has not yet been widely used, but gives promise of considerable value in rehabilitation work, since it operates best with the patient in the erect posture. The abdomen is covered by an inflatable rubber bag, which is held in place by a binder. Rhythmical inflation of the bag causes rhythmical expiration. Upon deflation the abdomen descends into position, and air is drawn into the lungs. This method of breathing corresponds to abdominal muscle breathing, and of course would be undesirable for retraining.

Effect of Gravity on Breathing

Gravity may have a marked influence on the muscle breathing pattern. So far we have described the patterns as observed with the body in the supine position. Analysis of breathing in this position is adequate during the early stage of recovery from paralysis. Rehabilitation, however, requires the patient to assume an erect position. When there is weakness of the respiratory muscles, the breathing pattern may be greatly altered while sitting or standing. Breathing may thereby become difficult or much easier.

In normal quiet breathing in the supine position, there is no abdominal muscle participation. On standing, however, there develops postural tone of the abdominal muscles. There may be greater tone during expiration than during inspiration. Vital capacity, however, remains approximately the same in both positions. There is usually a shift in the resting end-expiratory position, so that the expiratory reserve volume becomes greater than when supine, and the inspiratory capacity becomes less.

The effect of gravity on vital capacity and breathing ability in respiratory weakness is best illustrated by comparing two representative cases. On the one hand, let us consider a patient who has paralysis of all respiratory muscles, except those of the abdomen. Her vital capacity while supine is only 5 per cent normal. Since breathing is restricted to breathing in the expiratory reserve compartment and the expiratory compartment is normally increased on assuming the erect posture, this patient breathes more easily when erect. In fact, her vital capacity when erect is 15 per cent normal. In the supine position, breathing tolerance is less than one minute; in the erect position it is many hours.

In contrast, a patient has paralysis of all respiratory muscles except the diaphragm. He has a vital capacity of 15 per cent normal while supine and only one half that amount while erect. His breathing tolerance while supine is all day long and he has slept on occasion all night without respiratory aid. He tolerates sitting, however, for only a few minutes, unless he receives artificial respiration. Here again, the resting end-expiratory position is changed by changing to the erect posture. He depends on breathing in the inspiratory capacity compartment, which is decreased on assuming the erect position. In this case the diaphragm works to a disadvantage when erect; in the other, the abdominal muscles work to an advantage.

A properly fitting abdominal support will greatly aid breathing in the erect position with isolated diaphragm action, since it helps to keep the muscle in a position of working length. In the case of abdominal muscle breathing, however, an abdominal support will hinder breathing, since it shortens the working length of the abdominal muscles.

Efficiency and Automaticity of the Different Breathing Patterns

Recognition of the relative efficiency and automaticity of the different muscles of breathing is basic to proper management of respiratory muscle impairment. Clinical observation of numerous medical situations that influence breathing would lead to the assumption that the diaphragm is the most efficient and also the most automatic muscle of breathing. Even if the vital capacity is as low as 15 per cent normal, breathing may be done with ease and may be fully automatic and adequate during sleep—that is, provided this low vital capacity is due to diaphragm action.

Next efficient for breathing in the supine position are the muscles that expand the chest, especially the intercostal muscles. This appears logical, for normal quiet breathing includes chest expansion with diaphragm contraction. The efficiency of isolated chest muscle contraction is curtailed, however, by the passive reverse movement of the diaphragm. During the early weeks after an acute diaphragm paralysis, breathing is much embarrassed. It is doubtful that a patient with sudden isolated diaphragm paralysis will survive unless given artificial respiration. Usually, though, after several months of careful weaning from the respirator, the chest becomes quite efficient. The reason for this is not clear.

What has just been said about diaphragm and chest muscle action cannot be said about neck accessory muscles. When a patient uses the neck accessory muscles for breathing, one may say that breathing reserve is deficient. A rough estimate can be made of a patient's loss of breathing by noting just how much activity is necessary to bring in these muscles. Markedly increased breathing demand, even in the normal person, may cause neck accessory breathing. Thus an athlete after an exhausting physical feat will supplement strongly with the neck accessory muscles at every breath.

Isolated neck accessory breathing is less efficient even than isolated chest breathing. During the early months of rehabilitation, neck accessory breathing can be maintained only for a few minutes. With a gradual weaning program, however, this time may be built up to freedom from respiratory aid except for the sleeping hours, and provided, of course, that the neck muscles are strong. With isolated neck accessory breathing, as with isolated chest breathing, the diaphragm moves passively upward during each inspiration. This contributes to the inefficiency.

Abdominal muscle breathing is extremely inefficient in the supine position; but as is already discussed, it is quite efficient in the erect position. In no case, however, does it appear to be effective during sleep.

In most patients with respiratory muscle weakness, the involvement is scattered throughout the muscle groups so that usually the breathing patterns are mixed. Analysis of the movement pattern and the determination of efficiency and automaticity may thus become complicated.

Examination of the Diaphragm

Because of the special importance of the diaphragm in regard to its efficiency, its naturally great reserve of strength and because of its automaticity, one should be diligent in its examination. As before pointed out, the normal pattern should be well understood for proper evaluation of the abnormal. Diaphragmatic contraction is associated with the anterior displacement of the abdominal contents. Thus during inspiration, there is expansion of the abdomen as well as of the chest. This movement, however slight, is evidence of diaphragm function. During the early weeks of returning respiratory function, weak diaphragm movement is significant both in training as well as in the determination of prognosis.

More direct evidence of diaphragm movement is Litten's, or the diaphragmatic sign. If the patient is observed by proper oblique illumination, a shadow is seen moving down and up in the lower lateral intercostal spaces during inspiration and expiration respectively. The shadow corresponds to the level of contact between chest wall and diaphragm. If the patient's chest wall is well covered with adipose tissue, this sign is not visible. When seen, however, it is proof that the diaphragm contracts quite strongly on the corresponding side.

The most direct and most satisfactory method of examining the diaphragm is by X-ray or fluoroscopy. Movements can be seen that are not visible on physical examination. It is possible to determine asymmetrical movement and even to demonstrate paralysis of a segment of one leaf of the diaphragm.

In the presence of chest paralysis, abdominal distention resulting from diaphragm contraction is more obvious because of the contrasting chest retraction. In the adult, chest retraction is only moderate, even though the diaphragm contracts strongly. In the child, however, and especially in the infant, chest retraction may be marked. There appears to be a decrease in the transverse sectional area of the chest, which would impair the efficiency of the diaphragm. It should be recognized that in infants and small children, normally the chest may retract moderately during inspiration.

The diaphragm has a reserve of force or strength that is remarkable. Diaphragm force can roughly be measured by placing weights on the abdomen. The greatest weight that the patient can move easily would be the measure of his force. A normal subject is able easily to lift one hundred pounds, whereas a person with considerable weakness but still able to breathe easily with the diaphragm may be able to raise only two or three pounds.

A rough but clinically practical evaluation of the strength of the diaphragm can be obtained by manual testing. The examiner places his hands over the abdomen with fingers spread. He asks the patient to take a deep breath and push with maximal effort against the hand. Care should be taken that the patient does not raise the lumbar spine off the bed. The chief pitfall in manual diaphragm testing is met in the case that has good abdominal strength. This is especially true when the diaphragm is weak. When manual testing is attempted in such a case, the patient is likely to contract the abdominal muscles strongly. A false impression may thus be given that the diaphragm is active.

Conclusion

In a patient with weakness of the respiratory muscles, it should be recognized that the breathing is an integral part of all body functions. Breathing must be adequate and it must be continuously maintained. The study of the patient's muscle breathing pattern is a prerequisite for a proper analysis of the involvement, for determination of reliable prognosis, and for direction of rational treatment and rehabilitation. One should understand the strength of the various muscle groups, the breathing pattern under different conditions, the effect of fatigue and the effect of gravity. One should know normal breathing patterns and the natural efficiency as well as the automaticity of the different respiratory muscles.

Since return of muscle function varies with the diagnosis, this should be well established. Careful observation of the patient must be done at sufficiently frequent intervals and under the conditions of work and rest. Rehabilitation may be delayed if the patient develops a habit breathing pattern that is inefficient and exhausting. Furthermore, he may even be injured by exhaustion and anoxia and respiratory acidosis if the return of respiratory activity is not carefully directed.