MANUAL BREATHING AND COUGHING AIDS

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Although there is considerable debate in the medical literature about which methods of ventilatory assistance should be used to prolong the lives of patients with paralytic or restrictive ventilatory insufficiency, acute respiratory failure usually is triggered in these patients because respiratory muscles are unable to generate a cough sufficient to clear airway secretions during episodes of airway congestion. In many ways, the use of coughing aids is more important than the use of ventilatory aids.

STAGES OF COUGH

There are four stages involved in producing an effective cough.[3, 6] The first stage requires inspiring enough air to provide the necessary volume for a forceful cough. Generally, adequate inspiratory volumes for a cough are at least 60% of the predicted vital capacity (VC) for that individual. The second stage involves closing the glottis (vocal folds) to prepare for the abdominal and intercostal muscles to produce positive intrathoracic pressure below the glottis. The third stage is the active contraction of these muscles. The fourth stage involves opening the glottis and forcefully expelling the air.

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COUGH EVALUATION

The patient should be able to cough two to six times per expiratory effort. Coughs that have 6 to 12 L per second of transient peak expiratory flow rates[1] or a forced expiratory volume in 1 second of at least 60% of the patient's actual VC are good indicators of adequate muscle strength for effective expulsion. During a cough, alveolar, pleural, and subglottic pressures may rise as much as 200 cm H_2O.[5, 6]

An evaluation of the patient's cough mechanics should include asking the patient, "When you need to cough, what position do you use?" Then ask the patient to assume that position or assist him or her in assuming a posture as close to the preferred posture as possible. The patient should choose a posture that lends itself to trunk flexion. This is necessary for effective expulsion and airway protection. A "red flag" or inappropriate choice would be a preference for coughing while supine because this involves the opposite effect—trunk extension and poor mechanical alignment for airway protection.

Asking the patient to "show you a cough" is inadequate. Ask the patient, instead, to show how he or she would cough if there were secretions in the chest that needed to be coughed out.

An effective cough should maximize the function of each individual stage: (1) adequate inspiration, (2) glottic closure, (3) building up of intrathoracic and intra-abdominal pressure, and (4) glottic opening and expulsion. The clinician first should see a deep inspiratory effort paired with trunk extension, then a momentary hold, and finally a series of expiratory coughs on a single breath while the patient moves into trunk flexion.

1. Stage 1 (deep inspiration). Did the patient spontaneously inspire a deep breath before coughing or cough regardless of whether inspiring or expiring? Did the patient spontaneously use trunk extension, an upward gaze, or his or her arms to augment the inspiratory effort? Did the patient take enough time to inspire fully before coughing? An adequate inspiration should permit two to six coughs per expiratory effort for a cascade effect. Neurologically impaired patients who have inadequate inspiratory efforts usually present with only one or two coughs per breath and will generally produce a quieter and higher-pitched cough.[4]
2. Stage 2 (glottic closure). Did the patient hold his or her breath at the peak of inspiration before the expulsion phase, or did he or she go directly from inspiration to expiration? Did you hear a cough or a huff? A huff is a complete absence of a hold between inspiration and expiration. A huff, when the patient intended to cough, is an indication of insufficient glottic closure. This can result from a variety of conditions, including glottic edema following prolonged intubation, partial or full paralysis of the vocal folds, spastic hemiparesis of the vocal folds, timing or sequencing

difficulty secondary to brain injuries, and the presence of a tracheostomy. A lack of glottic closure will not produce any cough sound because the vocal folds are not approximating.

3. Stage 3 (thoracoabdominal pressure generation). The patient is observed for active contraction of the intercostal and abdominal muscles. Did the patient spontaneously move into trunk flexion during this phase? Did the cough have a low resonant sound? Inadequate force usually is heard as a higher-pitch cough, often called a *throaty cough.* The sound is quieter overall, and the patient does not produce as many coughs per expiratory effort. The coughs also sometimes are associated with neck extension rather than neck flexion as the patient attempts to clear the upper airway only. The air appears to leak out rather than be propelled out of the larynx during the cough. Inadequate pressures also prevent the patient from coughing more than once or twice on one expiratory effort.
4. Stage 4 (glottic opening and expulsion). Timing of glottic opening and the forceful expulsion of the air are observed in the fourth stage. During expulsion, does the patient appear to gag before successfully expelling the air? Does the patient seem to get stuck holding his or her breath? Deficiencies in this area often are related to brain injuries and coordination difficulties. The opposite also can occur. Patients with severe neurologic impairments or bronchospasms can get stuck at the end of expulsion and have difficulty initiating the next inspiratory effort.

Each stage can be analyzed individually to determine in what way the cough is inadequate. Once the deficit has been identified, steps can be taken to maximize the productivity of that particular stage. For patients with transient or permanent neuromuscular weakness or paralysis, detailed instructions may be necessary.[9, 10]

COUGH ASSIST INTERVENTIONS

Physically assisting the cough efforts of patients during the expulsion stage of the cough only addresses intervention in one stage. Care must be taken to look at all four stages to maximize the airway clearance potential of any assistive cough technique. First, the patient must be positioned properly. The beginning of any cough requires trunk extension or inspiratory movement to maximize inhalation, whereas the expulsion stage requires trunk flexion or expiratory movement to maximize expiratory flows.[9] For any given posture, the clinician must decide (1) if this posture allows for both trunk movements; (2) if flexion and extension are not possible or realistic, which movement is more important for that particular patient and if this posture facilitates this activity; (3) how gravity affects the muscle strength and function with this posture; and (4) if the patient still can protect the airway in this

posture. When these decisions are made, the clinician is ready to instruct the patient in the act of coughing.

An example may illustrate these instructions best. A clinician may choose a modified sitting position for a patient with generalized weakness. If the patient is slumped the clinician places a lumbar support, e.g., a lumbar roll, a towel, or even a pillow, behind the low back to increase trunk extension in that position. The patient is asked if he or she is comfortable and can swallow safely. Next, the clinician tries to maximize the first stage by asking the patient to take a deep breath. If the patient does not appear to take in a breath that approaches maximal inhalation, he or she is instructed further to: (1) "look upward while inhaling," (2) "raise both arms as high as possible while inhaling," (3) "squeeze the shoulders back while inhaling," and (4) "straighten or extend the back while inhaling," or some combination of them all. For those with more limited arm function, more subtle movements may be requested, such as (1) "bring your arms up and out while you inhale," (2) "rotate your arms outward while you inhale," or even (3) "turn your forearm up while you inhale."[7] Although less dramatic than the larger movements described previously, these subtle motions may increase the patient's inspiratory effort significantly and provide a more active means for the patient to participate in his or her own coughing program.

Stage 2 involves closing the glottis. For some patients with weakness or timing difficulties, a sharp, loud command to "hold it" at the peak of inspiration may be sufficient to facilitate closure. Remember to allow enough time for the patient to take in a deep breath before asking him or her to hold it. Some clinicians tend to rush the first phase by saying in quick succession, "Take a deep breath and hold it." This might induce the patient to shorten the inspiratory time unintentionally. A more appropriate verbal cue is, "Take a deep breath in . . . in . . . in . . . in . . . and now *Hold It.*"

Stages 3 and 4 are discussed together because they are interdependent. The patient now needs to move into trunk flexion, with or without the clinician's assistance, to maximize expulsion. For those patients who can assist, they can be asked to do the opposite of stage 1, such as: (1) "look down while you cough," (2) "pull your arms down to your hips as you cough," (3) "roll your shoulders forward while you cough," and (4) "bend your trunk forward while you cough." Likewise, patients with more limited arm function can be asked to: (1) "squeeze your arms to your chest while coughing," (2) "roll your shoulders and arms inward while coughing," or even (3) "turn your hands down while coughing." In this manner, the clinician has used every conceivable resource to maximize a voluntary cough. Even the weakest cough can be made more effective by applying these simple concepts; however, even with excellent instructions, many neurologic patients will require the clinician's physical assistance to inhale deeper or to exhale forcefully because of severe muscle weakness or paralysis.

ACTIVE ASSISTIVE COUGH TECHNIQUES

If after instruction and the aforementioned interventions the patient still cannot produce an effective cough, one of the following assistive approaches may be appropriate. Maximize the patient's active participation and effort in producing the cough. This may be accomplished by adding minimal verbal cues to improve overall timing or posture during an independent cough or by having the patient maximize eye movements. The latter is particularly useful for patients using ventilators who cannot move their extremities. Encourage the patient to be responsible for his or her care by teaching the concepts involved in producing an effective cough. This also can help the patient develop problem-solving skills. Modify and develop additional techniques on these principles.

Manually Assisted Techniques

Costophrenic Assist

The first assistive cough technique, the costophrenic assist, can be used in any posture. After assessing the most appropriate position for the patient (most often sitting or lying on one's side) and giving the patient instructions to maximize all four coughing stages, the therapist places his or her hands on the costophrenic angles of the rib cage. At the end of the patient's next exhalation, the therapist applies a quick manual stretch down and in toward the patient's navel to facilitate a stronger diaphragmatic and intercostal muscle contraction during the succeeding inhalation. The therapist also can apply a series of repeated contractions[11] throughout inspiration to facilitate maximal inhalation. The patient can assist the maneuver by actively using his or her upper extremities, head and neck, eyes, trunk, or all these to maximize the inspiratory phase. The patient then is asked to hold it. A moment before asking the patient to cough actively, the therapist applies strong hand pressure again downward and in toward the navel. In this manner, the therapist is assisting stage 3, building up the intrathoracic pressure, and stage 4, the force of expiration. Of course, the patient also would participate actively by using his or her arms, trunk, and so forth throughout the entire procedure.

This technique obviously is useful for patients with weak or paralyzed intercostal or abdominal muscles. It is helpful for lower chest compression but does not assist directly in upper chest compression unless the patient is able to move the upper body independently while the therapist assists the lower chest. This technique is easy to learn and teach and usually can be used from the acute phase through the patient's rehabilitation phase, thus accounting for its popularity; however, the therapist must remember to evaluate the effect of gravity in each posture to determine the best position for any cough assist technique.

Manually Assisted Techniques
Costophrenic assist
Heimlich-type or abdominal thrust assist
Anterior chest compression assist
Counterrotation assist

Self-assisted Techniques
Prone-on-elbows head flexion self-assisted cough
Long-sitting self-assisted cough
Short-sitting self-assisted cough
Hands–knees rocking self-assisted cough
Standing self-assisted cough

Heimlich-type Assist or Abdominal Thrust Assist

The second technique, the Heimlich-type assist or an abdominal thrust, requires the therapist to place the heel of his or her hand at the level of the patient's navel, taking care to avoid direct placement on the xiphoid process. After appropriate positioning, the patient is instructed to "take in a deep breath and hold it." Manual facilitation of inhalation is not feasible with this technique. As the patient is instructed to cough, the therapist quickly pushes up and in under the diaphragm with the heel of the hand, as in a Heimlich maneuver. The patient is instructed to assist with appropriate trunk movements as much as possible. Technically, this procedure is effective at forcefully expelling the air, but it is more invasive than the other techniques and can be extremely uncomfortable for the patient because of its (1) concentrated area of contact, (2) abrupt input that may elicit abdominal spasticity for some patients, which can interfere with the full assist, or (3) significant force that may cause an abdominal herniation or reflux. Because of its limitations, the Heimlich-type assist or abdominal thrust should be used only when the patient does not respond to other techniques and the need to produce an effective cough is imminent. Patients with low neuromuscular tone or flaccid abdominal muscles fare best with this procedure, but caution should be noted when there are sensory deficits, and it should not be used when the patient's stomach is full.

The therapist can simultaneously use the costophrenic and Heimlich-type assist techniques when the patient lies on his or her side. If the patient is hemiplegic or has a partial lung resection, thorax disease, or trauma, emphasizing one side of the thorax may be an appropriate focus during treatments for airway clearance. One of the therapist's upper extremities is used to perform the Heimlich-type assist while the other does a unilateral costophrenic assist. In this manner, the therapist can compress simultaneously all three planes of ventilation in the lower chest. Generally, less abdominal spasticity is elicited when the patient is lying on his or her side than when supine. The possibilities of combining

techniques and positions are endless once the therapist understands the principles on which they were developed.

Anterior Chest Compression Assist

The third assistive cough technique is called the *anterior chest compression* assist because it compresses the upper and lower anterior chest. This is the first technique to address the compression needs of the upper and lower chest in one maneuver. The therapist puts one arm across the patient's pectoralis region to compress the upper chest while the other arm is placed parallel on the lower chest or abdomen (Fig. 1). The commands are the same as for the other techniques. Because of the direct manual contact on the chest, inspiration can be facilitated easily, followed by a "hold." Thus, the therapist readily can enhance the first two cough stages. The therapist then applies a quick force with both arms to simulate the force necessary during the expulsion phase. The directions of the force are (1) inferior and posterior on the upper chest and (2) superior and posterior on the lower chest or abdomen. Performed together, the directed compression force from both arms makes the letter "V" on the patient's chest.

The anterior chest compression technique is more effective than the costophrenic assist for patients with weak chest wall muscles because of the added compression of the upper anterior chest wall. The author has found lying on one's side and three-quarter supine positioning to be the most effective positions for this technique. (Precaution, the anterior chest compression technique is not appropriate for patients with significant

Figure 1. Anterior chest compression assistive cough technique. Note therapist's arm position.

cavus deformities of the anterior chest because it promotes further collapsing of the anterior chest wall.)

Counterrotation Assist

In the author's clinical experience, the counterrotation assist is the most effective assistive cough for the widest cross section of neurologic patients. It is applied with the patient lying on his or her side. It is especially important for the therapist to be aware of any orthopedic lesions of the spine, rib cage, shoulder, or pelvis that may contraindicate use of the technique because of its strong vertebral rotary component.

The therapist begins by following the patient's breathing cycle with his or her hands positioned over the patient's shoulder and pelvis, as illustrated in Figure 2*A*. The therapist then gently assists the patient in (1) inhalation during trunk extension and (2) exhalation during trunk flexion to promote better overall ventilation and secretion motility before assisting the cough. This sequence generally is repeated for three to five cycles.

The patient is then ready to begin the coughing phase of the proce-

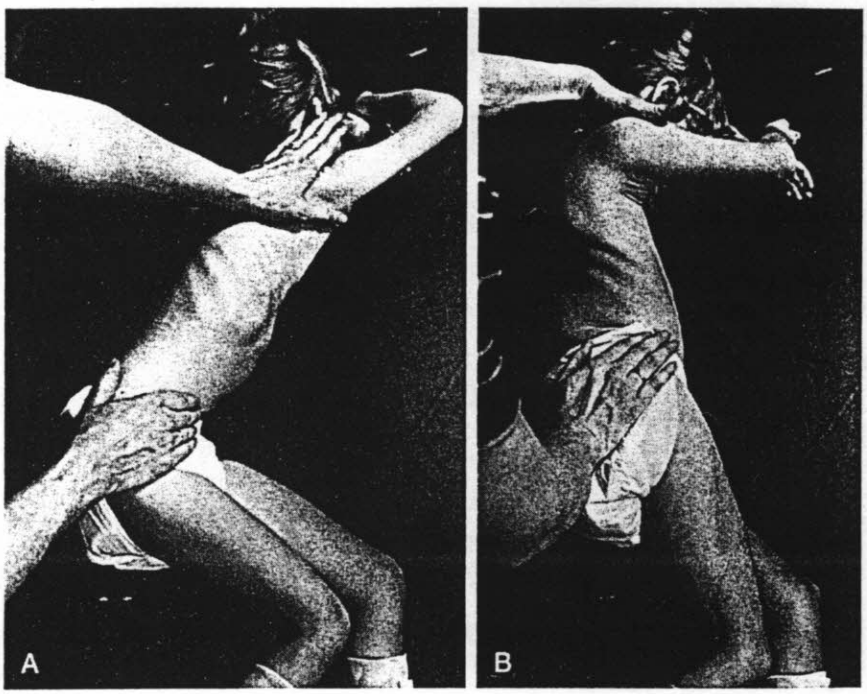

Figure 2. Counterrotation assistive cough technique. *A*, Facilitating inspiration before cough. Note counterrotational stretch on all three planes of chest expansion. *B*, Reversing the movement. Compressing the thorax on all planes to facilitate forceful expulsion.

dure. The patient is asked to take in as deep a breath as possible, with the therapist again assisting the patient in chest expansion. The patient is instructed to "hold it" at the end of maximal inspiration. The patient now is commanded to cough as hard as possible while the therapist quickly and forcefully compresses the chest and flexes the patient with his or her hands. The importance of following a true diagonal plane of facilitation during the flexion and extension phases of this technique cannot be overemphasized. Failure to do so will result in shifting of the air within the chest cavity rather than the desired forcing out. When done properly, the counterrotation assist is the only technique to close off the chest cavity rapidly in all three planes of ventilation in all areas of the chest. Unless the patient volitionally closes his or her glottis, it is impossible to withhold the air from being expelled forcefully. A common mistake, however, made by the therapist is that of pulling the patient back into trunk extension rather than into trunk flexion during the expulsion phase. A good rule is that if you can see your patient's face while you are applying the compression force, you have pulled the patient's thorax into extension. The head and neck should stay forward and flexed; thus only a facial profile should be seen (see Fig. 2*B*).

Another advantage is that the mechanics of this technique result in the rapid and forceful movement of air into and out of the lungs with no active participation necessary on the part of the patient. Incoherent or unresponsive patients, such as those with severe head trauma, cerebrovascular events, or cerebral palsy, still will have good airway secretion clearance with this technique. Obviously, patient participation is desirable to clear secretions even more effectively and for teaching the patient to clear his or her own secretions eventually.

Other effects of counterrotation make this procedure particularly beneficial to patients with low levels of cognitive functioning.

1. The rotation component is a natural inhibitor of high tone. This is the least likely of all techniques discussed to elicit an increase in abnormal tone. The opposite usually occurs. Gentle counterrotation before passively coughing a comatose patient can reduce hypertonicity, and it frequently reduces tachypnea. These two factors increase the potential for deeper inspiration and may reduce the possibility of the patient keeping his or her glottis closed during the expulsion phase.
2. Counterrotation is an excellent mobilizer for a tight chest. This can facilitate spontaneous deeper breaths. Tidal volumes, therefore, can be increased for many patients by mobilizing the chest walls.
3. Finally, rotation can be a vestibular stimulator and may assist in arousing the patient cognitively, allowing him or her to take a more active role in the procedure.

Clinical experience indicates that patients with extremely tenacious secretions tolerate the use of vibration better than quick chest compressions. Vibration with prolonged exhalation gives the secretions more

time to be moved along the bronchial tree for successful expulsion. In general, patients from all the diagnostic groups discussed are appropriate for this procedure. The majority find it to be the most comfortable and effective assistive means of expectorating secretions.

Self-assisted Techniques

The coughing techniques discussed are intended to be used as self-assist procedures and usually are taught later in a patient's rehabilitation process. Five different techniques are presented in detail: suggestions for variations are included. All self-assisted coughing techniques can begin as physically assisted techniques; however, because they are more active and require greater gross motor movement, they lend themselves to self-assisted techniques.

Prone-on-elbows Head Flexion Self-assisted Cough

Prone is not used frequently as a posture for coughing for patients with neuromuscular weakness because the position inhibits full use of the diaphragm by preventing lower anterior chest expansion and abdominal excursion. The resultant cough will be weaker than in other postures, and it should not be the exclusive posture used when assisting a cough. For the population of patients who can assume a prone-on-elbows posture independently, however, such as many tetraplegic patients, this technique may be effective. Many can assist their own coughs as needed rather than wait for someone to assist them to a sitting posture.

The head flexion assist method requires good use of head and neck musculature. It can be used as a self-assisted or therapist-assisted procedure, using the principles of trunk extension to facilitate inspiration and trunk flexion to facilitate expiration. With the patient prone on his or her elbows, the therapist instructs him or her to bring the head and neck up and back as far as possible, while breathing in maximally (Fig. 3). The patient then is instructed to cough out as hard as possible while throwing the head forward and down. This head and neck pattern initially can be assisted by the therapist to establish the desired movement pattern and gradually is advanced to a resisted pattern to promote increased accessory muscle participation and to strengthen those muscle groups.

Long-sitiing Self-assisted Cough

For the tetraplegic long-sitting self-assisted cough, the patient is positioned on a mat in a long-sitting posture (legs straight out in front of the patient) and with upper extremity support. The therapist instructs the patient to extend his or her trunk backward while inhaling maximally (Fig. 4). The therapist then tells the patient to cough as the patient

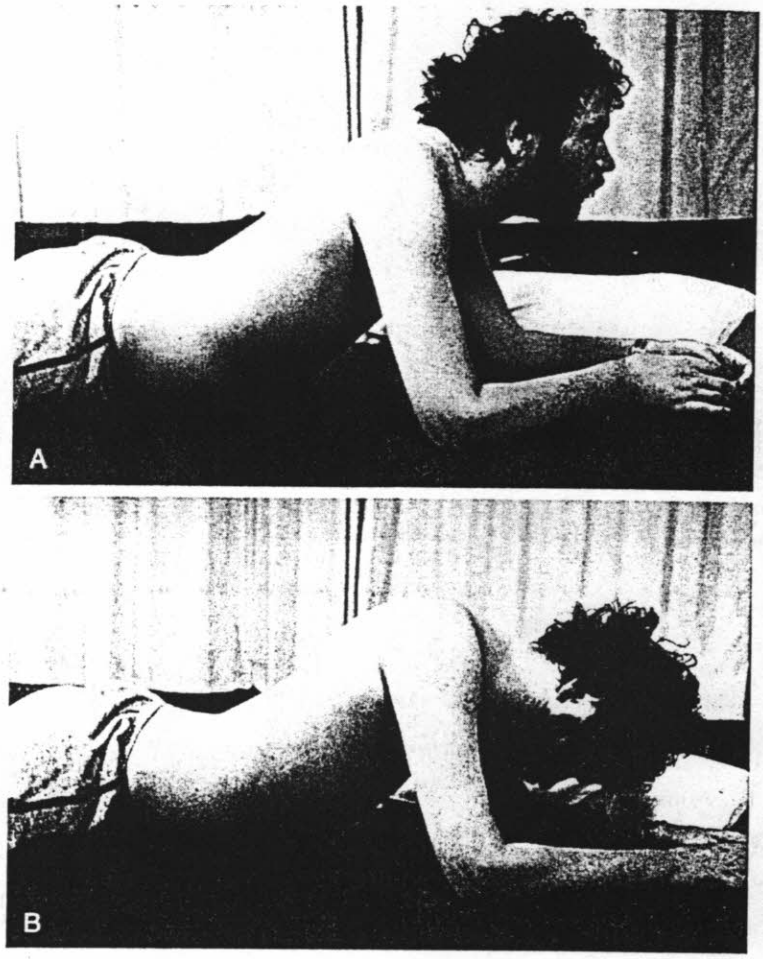

Figure 3. Prone on elbows, head flexion self-assisted cough technique. *A*, Inspiratior phase. Patient is instructed to look up and take in a deep breath. *B*, Expulsion phase Patient is instructed to look down and cough.

throws his or her upper body forward into a completely head- and neck-flexed posture and uses shoulder internal rotation, if able. The extension aspect of the procedure is used to maximize inhalation, whereas the flexion aspect is used to maximize expiration. The self-directed chest compression occurs mainly on the superior–inferior plane of ventilation only.

The paraplegic long-sitting assist employs the same principles as the tetraplegic long-sitting assist. Paraplegics, however, have active trunk extension musculature and can achieve greater trunk extension and flexion. They, therefore, can achieve greater chest expansion before the cough and greater chest compression on a superior–inferior plane during

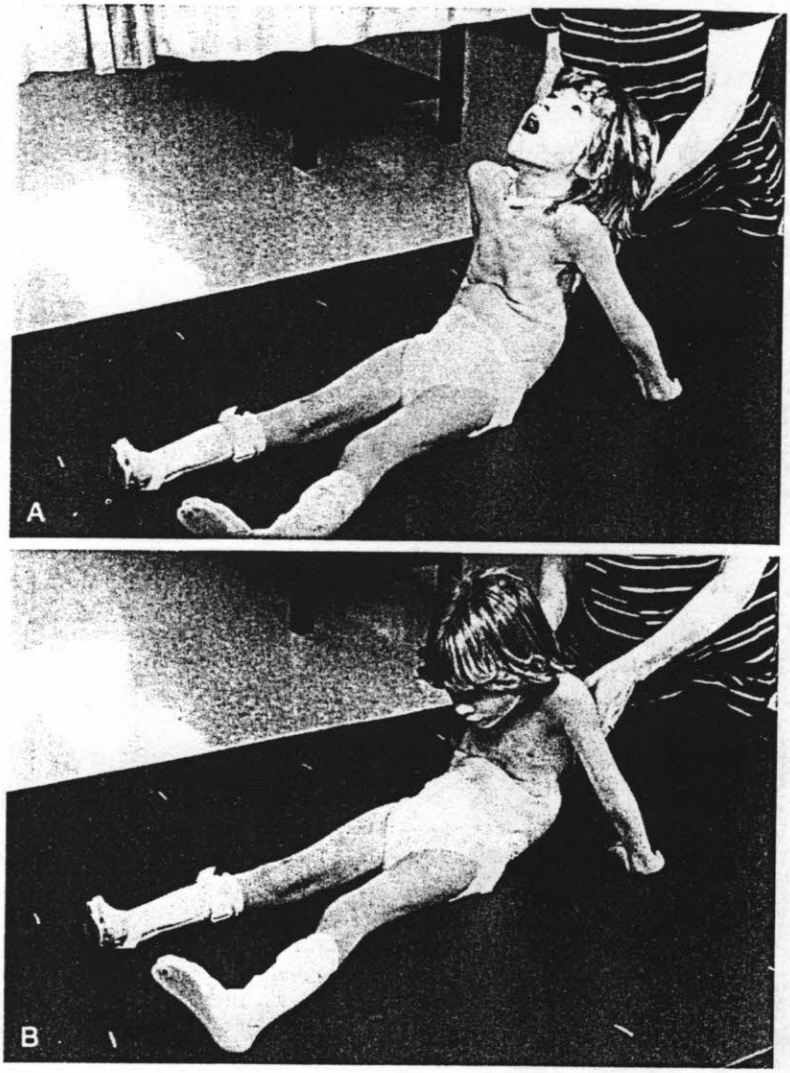

Figure 4. Long-sitting self-assisted cough technique. *A*, Inspiration phase. Note patient's use of eye gaze, mouth opening, and shoulder external rotation. *B*, Expulsion phase. Note downward eye gaze, shoulder internal rotation, and trunk flexion.

the cough. The patient positions his or her upper extremities in a butterfly position or uses elbow retraction, depending on the level of the spinal cord lesion. During the flexion phase, the patient throws himself or herself forward, compressing the upper and lower chest. This can be used successfully by patients with paraplegia, provided that they do not have any interfering spasticity. If the patient lacks hip flexion or is worried about bony contact or skin injury, place a pillow or two on

the legs (lap). This limits the hip flexion and minimizes trauma from the quick thrust onto the legs.

Short-sitting Self-assisted Cough

The third assistive cough in sitting, the short-sitting self-assist, typically is performed in a wheelchair or over the edge of a bed. The patient is instructed to place one hand over the other at the wrist and place them on his or her lap. As in the previous technique, the patient then is asked to extend the trunk backwards while inhaling maximally. This is followed by a strong voluntary cough. During the cough, the patient pulls his or her hands up and under the diaphragm. This resembles the motion of a Heimlich maneuver (Fig. 5). The hands substitute for abdominal muscle activity in pushing on the intestinal contents, and in this way they facilitate diaphragm excursion. It is an effective self-assisted method for patients who have weak diaphragms or abdominal musculature. Most tetraplegic patients at levels of C5 or below successfully can learn this technique. Tetraplegics usually require trunk support from their wheelchairs to perform it independently and safely, whereas most paraplegics can perform it from an unsupported short-sitting position. Patients who lack good upper extremity coordination, such as many

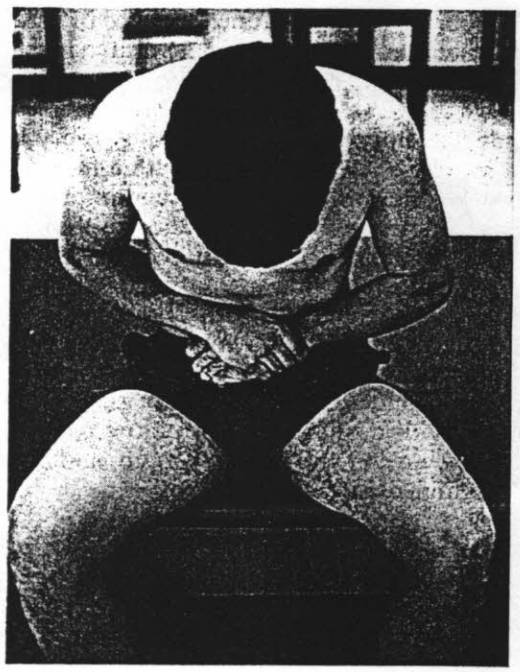

Figure 5. Short-sitting self-assisted cough technique. Note use of hands and upper extremities like a Heimlich maneuver.

patients with Parkinson's disease and multiple sclerosis, cannot perform the procedure quickly or forcefully enough to make it effective and usually require assistance from another person.

Variations on all techniques performed with the patient in the sitting position readily can be made. Use the concepts explained to develop techniques that work for your patients. For example, ask your wheelchair patient to lift his or her arms while inhaling, "to hold," and then to cough while throwing the arms down toward the feet or lap and using maximum trunk flexion. Use of a seat belt can increase safety. In another example, have the patient hook one arm on a push handle of the wheelchair and move the other upper extremity up and back (as in a proprioceptive neuromuscular facilitation D_2 pattern[11]). The moving hand should maximize trunk rotation. The patient inhales during the movement, "holds," and again coughs as the trunk and upper extremity are thrown down toward the opposite knee. When devising the most appropriate self-assisted cough for a patient, it is important to use a combination of trunk, upper extremity, head, neck, and eye movement patterns to maximize all four phases of cough.

Hands–Knees Rocking Self-assisted Cough

The last assistive cough discussed is performed most frequently as a multipurpose activity. It can be useful for increasing the patient's balance, strength, coordination, and functional use of breathing patterns, including quiet breathing and coughing simultaneously. The patient assumes an all-fours position (on hands and knees). He or she is then instructed to rock forward, looking up and breathing in while moving to a fully extended posture (Fig. 6). After this, the patient is told to cough out while rocking back on the heels with a flexed head and neck. The importance of the flexion and extension components of a cough is noted. The rocking can be done with or without a therapist's assistance. For patients with generalized or spotty weakness throughout, this method is perfect for incorporating many functional goals into a single activity. It can help prepare patients for the more challenging respiratory activities that they undoubtedly will meet after discharge from a rehabilitation center.

For patients with limited lower extremity range of motion or skin concerns associated with a quick force, a pillow can be placed on the calves, limiting knee flexion during the cough and preventing direct contact of bony prominences.

Standing Self-assisted Cough

While standing, the same principles can be used for self-assisted coughs that are used for sitting patients provided that the patient has adequate standing balance or upper extremity support. Use any technique described and modify for this higher developmental posture.

Figure 6. Hands-knees rocking self-assisted cough technique. *A*, Inspiration. Head up, eyes gaze up, and forward rocking motion. *B*, Expulsion. Backward thrust onto the patient's heels. The abdominal viscera provide the expulsion force.

Combinations of trunk, head, and extremity movements during the cough maneuver are almost endless.

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