An innovative approach to assistive cough techniques

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BOTH IN THE literature and in the clinical setting, patients with spinal cord injuries (SCI) have been shown to be at great risk for developing respiratory complications, even after their acute phases have subsided.[1-3] Neuromuscular impairment of the respiratory musculature limits patients' ability to adequately expand their chest for optimal respiratory function.[4-6] SCI patients with high cervical involvement (C-1-C-5) directly affecting the function of the diaphragm and upper accessory muscles will demonstrate a profound decrease in chest expansion.[3,7,8] However, perhaps not so obvious is a similar dysfunction in SCI patients with thoracic involvement. Their intercostal muscles (T-1-T-12) and abdominal muscles (T-5-T-12) will be impaired, which will substantially limit lateral costal chest expansion and forceful exhalation.[3,9] Indirectly all SCI patients' respiratory function is further compromised by their inability to independently move in and out of all the developmental postures. This eliminates

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or severely reduces the positive role that gravity plays in natural secretion drainage, making them more susceptible to secretion retention and subsequent infections or blockages.[10] Clinically the SCI population will demonstrate decreased pulmonary functions, especially for vital capacities and cough effectiveness.[11-13]

Eliminating or minimizing respiratory risk should be a long-term goal for all SCI rehabilitation programs. One aspect of respiratory care is secretion drainage, which can be managed through a variety of techniques such as percussion, vibration, mechanical assistance, therapeutic exercises, and assistive cough techniques.[14-16] This article concerns itself with the last technique.

The effectiveness of the assistive cough with SCI patients has been documented in the literature.[17,18] However, in the majority of cases only a few techniques have been documented, and these have used few postures of the developmental sequence.[17-19] A common assistive cough uses manual compression of the lateral costal borders of the rib cage in supine during the expulsive phase of the cough.[18,20] What happens to these patients when they need to clear their lungs while in another posture or when these few techniques are ineffective? This article explores these problems and presents alternatives. It proposes several choices of assistive cough techniques performed in various postures of the developmental sequence, which more appropriately handles the wide range of neuromuscular impairments and respiratory needs of this patient population.

In all, 12 assistive cough techniques in five developmental postures are presented (see box). Prior to describing the techniques the effects of gravity on neuromuscular tone (spasticity, flaccidity), muscle strength, and breathing patterns are discussed.

Assistive Cough Techniques

1. Supine
   - Costophrenic assist
   - Anterior chest assist
   - Heimlich-type assist
2. Sidelying
   - Costophrenic assist
   - Heimlich-type assist
   - Combination of costophrenic and Heimlich-type assists
   - Massery counter-rotation assist
3. Prone-on-elbows
   - Head flexion assist
4. Sitting
   - Quad long sitting assist
   - Para long sitting assist
   - Short sitting assist
5. Hands-knees
   - Rocking assist

SUPINE

Respiration takes place in three directions anatomically expressed as the anteroposterior plane, the superior-inferior plane, and the transverse or lateral plane.[4,17,21] All three planes of respiration

All three planes of respiration must be assessed before deciding on an appropriate posture for a specific patient.

must be assessed before deciding on an appropriate posture for a specific patient. In supine, anterior chest expansion will be in a gravity-resisted plane; lateral and superior-inferior expansion will be in a gravity-eliminated plane; and posterior expansion will be posturally inhibited. Because of this, SCI patients with significantly weakened diaphragms, intercostal muscles, or pectoralis muscles (below a "fair" grade)[22] will find it extremely difficult to breathe into the anterior plane of respiration. Therefore these patients will be less likely to achieve their maximal inspiratory potential in supine, which will be expressed as a decrease in their vital capacity. Spasticity of the trunk muscles, especially the abdominal and intercostal muscles, tends to increase in this posture due to the stretch on those muscles caused by extension of the trunk.[23] This renders the chest less mobile and thus less able to fully expand before the spasticity interferes with the chest's movements.

For the above SCI patients, supine is perhaps the most difficult posture in which to achieve an effective cough. Patients with lower tone or those with muscle grades at "fair" or above fare better. Unfortunately, patients who are medically unstable, such as those with unhealed spinal fractures, may be limited to supine, thus eliminating other postural choices.

The first technique is called the costophrenic assistive cough, one of the most commonly known techniques used in the clinical setting.[18,20] With hands on the costophrenic angle of the rib cage (Fig 1), the therapist applies a quick manual stretch, inferiorly and medially, to facilitate a stronger diaphragmatic and intercostal contraction prior to instructing the patient to "take a deep breath." The patient then inspires maximally and is told to "hold it." Prior to the command to "cough," the therapist applies strong manual pressure superiorly and medially. This assists forced expiration by increasing intrathoracic pressure. The disadvantage of this technique is that only lower chest compression is assisted. The upper chest movements remain unguided by the therapist.

Fig 1. Costophrenic assist in supine.

Another option for the supine position is the anterior chest assist. Modifying the above technique, the therapist places one hand or entire forearm across the lower anterior chest wall. The other hand or forearm is placed across the upper chest over the sternum (Fig 2). The same instructions are given to the patient. Now the therapist can stabilize or compress the upper chest as needed during the active phase of the cough. This generally requires more skill on the part of the therapist and thus may be more difficult for family members to master for home use.

The third technique is called the Heimlich-type assistive cough. The heel of the therapist's hand is placed just inferior to

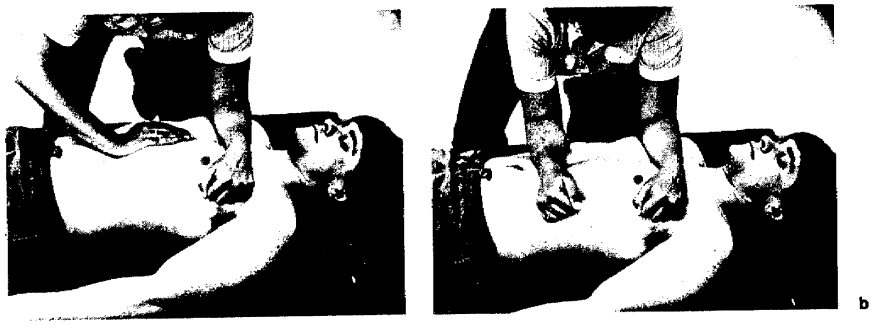

Fig 2. Anterior chest assist in supine. **(a)** Therapist provides assist inferiorly below the xiphoid process and along the anterior aspect of the upper chest. **(b)** Therapist provides assist along the length of the lower chest by using entire forearm.

the patient's xiphoid process, avoiding contact with the lower ribs (Fig 3a). The patient takes in a deep breath and coughs out while the therapist applies a quick thrust superiorly and posteriorly with the heel of the hand (Fig 3b). This resembles the force of a Heimlich choking maneuver, thus its name. However, like the choking maneuver it can be extremely uncomfortable for the patient due to its concentrated area of contact on the abdominal contents and the force of application. In addition, its abrupt nature and sensory input to the abdominal muscles may elicit undesirable trunk spasticity.

Due to its disadvantages, this assist is recommended only for (1) home use because of its ease of application and generally effective results; (2) patients with flaccid abdominal tone and sensory loss to the contact area; and (3) the patient who does not respond to other techniques and in whom the need to

Fig 3. Heimlich-type assist. **(a)** Therapist's hand placement is inferior to the xiphoid process. **(b)** Final hand position. Cough has been facilitated by a quick thrust posteriorly and superiorly.

produce an effective cough in supine is urgent. Like the costophrenic technique, this assistive cough uses only compression of the lower chest.

SIDELYING

When the spine is stabilized, sidelying appears to be a more effective posture. The effects of gravity on the planes of respiration change. Now anteroposterior as well as inferior-superior chest expansion become gravity-eliminated movements while uppermost lateral expansion becomes gravity resisted. The lower lateral side is now the one posturally inhibited. Thus the anterior chest wall muscles, which had to resist gravity in supine, can function in a gravity-eliminated plane. This is ideal for quadriplegics with less than a "fair" grade in those muscle groups. In addition, this posture allows for easier inhibition of trunk and limb spasticity through more flexion posturing or other inhibitory techniques, making it more appropriate for the high-toned patient.[23,24] The asymmetry of this posture lends itself to easier inferior excursion of the diaphragm on the uppermost side because of the lateral shift of the diaphragm and intestines toward the lowermost side due to gravity.[3] The value of this asymmetry must be assessed according to each individual patient's needs.

The first technique in sidelying is the costophrenic assist, now performed unilaterally to the uppermost side, thereby only assisting the patient in lateral lower chest compression (Fig 4). The commands to the patient remain the same as in supine. Lateral chest excursion, now antigravity, provides a natural progression from supine for patients whose intercostal

Fig 4. Costophrenic assist in sidelying. Only unilateral facilitation is possible.

muscle strength is improving to a "fair" grade or better. Thus this technique can be used as a muscle strengthening and timing activity for parapaplegics with chest muscle impairments. For quadriplegic patients, the costophrenic assist in sidelying provides a greater challenge to trunk balance while requiring the performance of the functional skill of coughing.

The second technique presented in this posture, the Heimlich-type assist, is administered as described in supine. However, one major component is different. Because sidelying offers the therapist more control over the patient's spasticity, the Heimlich-type assist is significantly less likely to elicit an increase in trunk spasticity here than in supine.[23,24] Thus, unless medically limited to supine, the Heimlich-type assist is best performed in sidelying.

The third assistive cough technique in sidelying uses a combination of the costophrenic and Heimlich-type assist. The therapist places one hand on the uppermost lateral aspect of the chest, as in the costophrenic assist, while the other hand is placed anteriorly, as in the Heimlich-type assist (Fig 5). More planes of respira-

Fig 5. Combination of the costophrenic and Heimlich-type assists in sidelying.

tion are then used during the expulsion phase of the cough. The therapist can now simultaneously compress the anterior-inferior and lateral planes of the lower chest, making this technique more effective at clearing secretions than either technique alone. The combination assist does not involve rotation around the spine; therefore it is appropriate for those patients who can assume the sidelying position but cannot be rotated around the trunk axis. However, it is usually more difficult to teach to the family than either technique by itself.

The final assistive cough in sidelying, the Massery counter-rotation assist, appears to be the most effective assistive technique for clearing of secretions.[25] With the patient positioned as shown in Fig 6, the therapist kneels or half kneels behind the patient at his or her hips, diagonally facing the patient's shoulder area (roughly a 45° angle). If the patient is lying on the left side, the therapist's left hand should be placed squarely on the patient's right scapula, and the right hand should be placed over the patient's right anterior-superior iliac spine (ASIS). Following the patient's natural respiratory cycle, the therapist asks the patient to take a deep breath in while pushing the patient's upper thorax superiorly and anteriorly with the left hand and pulling the patient's pelvis inferiorly and posteriorly with the right (Fig 6a). This produces counter-rotation of the thorax and facilitates greater expansion of the chest in all three planes of respiration. The patient is then instructed to "hold it" (the air) while the therapist switches hand placement. The left hand slides forward over the pectoralis region, avoiding direct placement on the patient's clavicle or humerus. The right hand slides posteriorly into the gluteal fossa.

The therapist is then ready to asist the patient in the expulsive phase of the cough (Fig 6b). The patient is told to cough out while the therapist pulls the upper chest (left hand) inferiorly and posteriorly and pushes the lower chest (right hand) superiorly and anteriorly in a diagonal plane. This closes off all three planes of respiration, forcing the air out of the lungs, regardless of the level of active patient participation. Unless the patient cognitively keeps the glottis closed, it is impossible for him or her to prevent the air from being forcefully expelled. It is the only assistive cough technique described here or in the literature that uses compression of both the upper and lower chest in all three planes of respiration simultaneously. Clinically the Massery counter-rotation assist appears to be a very effective cough assist for patients off all spinal precautions.

Some precautions do exist for this last technique. First, the Massery assist

Fig 6. The Massery counter-rotation assist. **(a)** Inspiration is facilitated by counter-rotation of the upper chest superiorly and anteriorly and the lower chest inferiorly and posteriorly. **(b)** Forceful expiration is produced as the chest is compressed in the opposite direction.

requires significant counter-rotation of the spine; thus medical clearance ensuring spinal stability is required before its initiation. Second, the therapist must maintain firm hand contact using only the heel or flat of the hand to prevent gouging the patient with the therapist's fingertips or thumbs. In this way pressure is distributed over a greater contact area, maximizing patient comfort and therapist control. Finally, the therapist's position on a true diagonal plane to the patient's body is crucial to the success of this techique. The rotation component and thus the lateral compression of the chest is developed through the therapist's position. A common error is made when the therapist is in a position perpendicular to the patient. The force then applied through the patient's thorax is primarily on an anteroposterior plane, which may simply cause the air to shift within the chest cavity, rather than forcing it out.

The major advantages of this procedure are that the Massery counter-rotation assist is the only technique that simultaneously compresses the chest in all three planes, mechanically forcing the air out of the lungs. Second, since rotation appears to relax hypertonic muscles,[26] this technique may further decrease the patient's tone, enhancing the potential of a more productive cough. In addition, the rotational stretch on the chest during the inspiratory phase of the cough serves as an excellent chest mobilizer. Decreased tone and improved mobility can then facilitate an increase in the patient's inspiratory capacity. This would promote better aeration around secretions prior to coughing. Last, active patient participation is not required for producing effective results; therefore the Massery assist is appropriate for the entire SCI population once they have achieved spinal stability.

PRONE

The effects of gravity again change in the prone position. Superior-inferior expansion remains in a gravity-eliminated plane joined again with lateral expansion. Posterior expansion becomes gravity resisted for the first time, while anterior expansion becomes posturally inhibited. Anterior postural inhibition holds special significance for this patient population. The majority of SCI patients, whether paraplegic or quadriplegic (below a C-4 level), are diaphragmatic or "belly" breathers.[3,7,27] They are primarily breathing in the inferior and anterior planes of respiration. Lateral expansion is often severely limited, if not absent, due to the lack of innervation to the intercostal muscles, which provide the majority of lateral chest expansion.[3,7,28] Therefore, due to postural inhibition of the anterior chest movements, SCI patients in flat prone may find diaphragmatic breathing difficult, causing panic and possibly shortness of breath. The therapist must take great care to determine if the patient can adequately compensate for this anticipated loss of diaphragmatic use prior to placing him or her in prone. Prone may be a more effective position for control of spasticity than supine; however, it appears to be less effective than sidelying. The risk is that the patient's tone may increase undesirably due to anxiety over being prone.

The head flexion assistive cough is performed in prone-on-elbows rather than prone. The prone-on-elbows position frees up the anterior upper chest, allowing gravity to assist chest expansion. This is the first posture in which gravity is seen to *assist* any respiratory muscles. The lower anterior chest remains posturally inhibited, primarily limiting diaphragm and abdominal muscle function. It is also the first posture to demand some upper extremity stability and head and neck control. Because of these factors, prone-on-elbows is considered a more advanced posture for respiratory retraining, especially for those patients with cervical level involvement.

In the head flexion assistive cough in prone-on-elbows, the upper extremities are fixated, allowing the pectoralis muscles to act as upper chest expanders. The neck muscles are placed on stretch, allowing more upper chest movement to occur. Respiration can be facilitated by incorporating inhalation with head, neck, and trunk extension and expiration with corresponding flexion. For this reason the patient is instructed to elevate and extend the head back as far as possible while inhaling deeply (Fig 7a). The patient is then instructed to cough out as hard and fast as possible while fully flexing the head (Fig 7b). Depending on each patient's needs, these motions can be assisted or resisted by the therapist or can be performed by the patient as an independent activity.

Respiration can be facilitated by incorporating inhalation with head, neck, and trunk extension and expiration with corresponding flexion.

The cough produced with the head flexion assist will be weaker than in other postures, since only the upper chest is significantly involved. This represents a

Fig 7. Head flexion assist in prone-on-elbows. **(a)** Patient actively extends neck on inspiration. **(b)** Head and neck are flexed while the patient coughs.

change from some of the other techniques that only assisted through lower chest compression. The purpose of this technique is not to ensure maximal clearance of secretions but rather to promote use of these accessory muscles in the functional respiratory activity of cough production. Once use of the accessory muscles is mastered in prone-on-elbows, the patient should be progressed to a posture in which both diaphragm and accessory muscles can be incorporated to maximize cough effectiveness. For very few quadriplegic patients the head flexion assist may be used functionally if they can independently assume the position.

SITTING

The sitting position is the first upright posture, and for many SCI patients the only upright posture, that will be attained. Superior-inferior expansion, which has always been in a gravity-eliminated plane, is now more directly affected by gravity. Superior expansion becomes gravity resisted, therefore resisting the motions of the upper chest accessory muscles while inferior expansion becomes gravity assisted, therefore assisting inferior diaphragmatic excursion. However, the intestines are also affected by gravity, shifting pronouncedly inferior and anterior due to a weakened or flaccid abdominal wall.[4,5] These patients may require the help of an abdominal binder or body jacket to reposition their intestines more advantageously under the diaphragm.[29-31] All other planes of respiration are in a gravity-eliminated plane. This is the first posture where no plane of respiration is posturally inhibited. The influence of tone was a significant consideration in choosing the previous postures. However, tone cannot be controlled easily in sitting due to the inherent instability of this posture with the SCI population.

Sitting is usually the most functional posture for the SCI patient. The three assistive coughs described in this posture are intended to be independent self-assisted coughs. They allow the patient to independently facilitate a stronger cough when needed, not just when a caretaker is available. Most SCI patients below a C-4 level can learn to perform at least one of these techniques independently.

The first assistive cough, the "quad long sitting assist," is geared toward the quadriplegic population and is performed

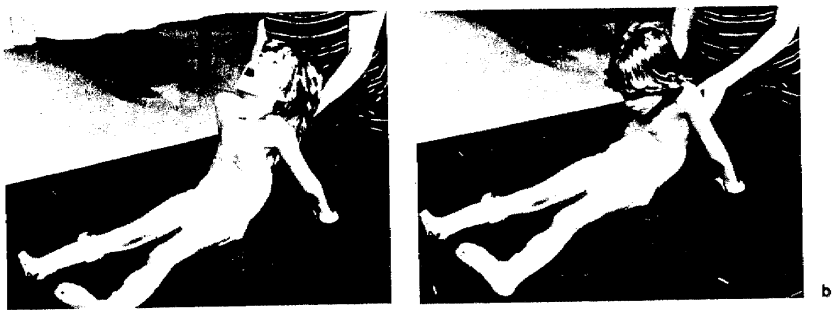

Fig 8. Quad long sitting assist. **(a)** Upper chest expansion is facilitated by upper extremities positioned in extension and external rotation with head and neck extension. **(b)** Mechanical closure of upper chest as head and neck are flexed forward.

in a long sitting posture. The patient sits on the floor, mat, or bed with legs extended. The trunk is supported by mechanically locking the upper extremities in elbow extension, shoulder extension, and external rotation. The therapist instructs the patient to fully extend the head and neck backward while inhaling deeply (Fig 8a). The patient is then instructed to cough out while quickly flexing the head and neck forward to aid in the mechanical closure of the upper chest (Fig 8b).

The "para long sitting assist" cough is intended for the paraplegic patient and is a modified version of the quad long sitting assist. The patient inhales, arching the back and retracting the scapulae by bringing the elbows back (Fig 9a) or by flexing the arms up and over the head. The patient then coughs and simultaneously flexes the trunk forward, extending the arms toward the feet as far as possible (Fig 9b). Although requiring greater trunk balance than previous postures, this assist effectively uses the prin-

Fig 9. Para long sitting assist. **(a)** Trunk extension with scapular retraction enhances inspiration. **(b)** Trunk flexion assists expiration.

ciple of facilitating inhalation with trunk extension and exhalation with trunk flexion. The inferior plane of respiration is compressed through trunk flexion, making clearing secretions during a coughing maneuver more effective in the para long sitting assist than the quad long sitting assist, which only minimally assists lower chest compression.

The third sitting assistive cough is performed in short sitting, such as in a wheelchair or over the edge of a bed. The patients are instructed to place their hands in their lap. Patients with adequate hand function grasp their hands, one over the other. Patients with only biceps (C-5) or wrist extensors (C-6) are instructed to overlap their forearms at the wrist. As in the previous technique, the patient is initially instructed to use full extension of the upper body to facilitate a maximal inhalation. The patient is then told to cough while throwing his or her upper body into full flexion and simultaneously pulling the interlocked forearms up and under the diaphragm as in a Heimlich choking maneuver (Fig 10). Functionally, the upper extremities are trying to replace the vital role that the abdominal muscles play in producing an effective cough. Lack of trunk stability generally makes the short sitting assistive cough in a wheelchair the easiest one for the higher level quadriplegic patient to master. For safety, it is recommended that patients wear their seatbelts during the maneuver. Patients below C-7 can more consistently use either the long or short sitting technique.

Fig 10. Short sitting assist. A self-assisted cough technique whereby the patient uses upper extremities to force diaphragm superiorly during a cough.

HANDS-KNEES

The last posture discussed for assistive cough techniques shows gravitational effects similar to those of prone-on-elbows. Superior-inferior and lateral expansion are gravity eliminated, posterior expansion is gravity resisted, and anterior expansion is gravity assisted. The significant difference here is that no plane of respiration is posturally inhibited, and the trunk is unsupported. It is more physically demanding than prone-on-elbows or sitting, making it a more advanced posture for respiratory retraining. For those patients who can handle the physical requirements of the posture, such as those with incomplete cervical injuries or lower thoracic injuries, it offers the chance to integrate balance, strength, and coordination skills with functional breathing skills such as coughing. This promotes better long-term carry-over of respiratory skills.

On hands and knees the patient rocks forward and extends the head and neck,

Fig 11. Hands-knees rocking assist. **(a)** Rib cage is elongated as patient rocks forward inhaling maximally. **(b)** Coughing occurs as patient rocks back onto heels.

inhaling maximally (Fig 11a)..The patient then rocks back onto the heels quickly, flexing the head while concurrently coughing (Fig 11b). The influence of trunk extension and flexion on inspiration and expiration is again utilized. This activity can be performed independently, assisted for weaker patients or resisted for the more advanced patient. All can be very effective mobilizers of lower lung congestion. The rocking assist can also be done on an angle board in a slight head-down position to enhance more secretion drainage.

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Selecting the most appropriate of the 12 different techniques for each patient will depend on a number of factors. These include (1) medical precautions, (2) the extent of respiratory muscle paralysis, (3) tonal problems (spasticity), (4) specific lung or lobe involvement, (5) the planes of respiration needing the most assistance, and (6) the need for a patient-assisted or therapist-assisted technique. The SCI patient population will always be at risk for developing respiratory complications, but with proper use these assistive cough techniques can help to minimize potential respiratory problems.

While the intent of this article is to illustrate assisted coughing techniques, the above procedures can be modified and used to address other respiratory goals, such as increasing rib cage mobility, increasing vital capacity, and improving breathing patterns. The coughing techniques can likewise be used for any patient needing respiratory rehabilitation secondary to a neuromuscular disorder (eg, cerebral palsy, hemiplegia, head trauma, multiple sclerosis, and Parkinson's disease.)[25]

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