

Behavioral Management of Respiratory/Phonatory Dysfunction From Dysarthria: A Flowchart for Guidance in Clinical Decision Making

Kristie A. Spencer, Ph.C.

*Department of Speech and Hearing Sciences
University of Washington
Seattle, Washington*

Kathryn M. Yorkston, Ph.D.

*Department of Rehabilitation Medicine
University of Washington
Seattle, Washington*

Joseph R. Duffy, Ph.D.

*Division of Speech Pathology
Department of Neurology
Mayo Clinic
Rochester, Minnesota*

This work emerged from a larger effort by an Academy of Neurologic Communication Disorders and Sciences committee to establish Practice Guidelines for the management of speakers with dysarthria. A fundamental issue in dysarthria management is the availability of appropriate methods for assessing and treating speakers with compromised respiratory and phonatory subsystems. As such, a flowchart of behavioral management options for respiratory/phonatory dysfunction from dysarthria is provided. Three general areas of respiratory/phonatory dysfunction are identified to provide an organizing framework for a clinician's approach to respiratory/phonatory management. Those areas include (a) decreased respiratory support, (b) decreased respiratory/phonatory coordination and control, and (c) reduced phonatory function. Within each area, behavioral techniques are delineated in terms of the available support from the dysarthria literature. Support for a particular treatment may stem from evidence-based intervention research or expert opinion. Behavioral techniques lacking support also are highlighted, as are areas in particular need of treatment efficacy research.

Pathologies of the central or peripheral nervous system often lead to dysarthria. Respiratory and phonatory subsystem disruption is a common manifestation of dysarthria and can have a formidable impact on the adequacy of speech production. Treatment of the respiratory and phonatory subsystems is often given priority because improvements at this level are believed to generate improvements in other aspects of speech as well (Hayden & Square, 1994; Netsell & Daniel, 1979; Ramig, 1992; Rosenbek & LaPointe, 1985; Yorkston, Beukelman, Strand, & Bell, 1999). The management of respiratory/phonatory dysfunction, therefore, is often a fundamental element of the therapeutic process when providing services to speakers with dysarthria.

This article was motivated by the development of practice guidelines for the behavioral management of respiratory/phonatory dysfunction from dysarthria; it is the companion article to the review by Yorkston, Spencer, Duffy, and colleagues (this issue). Practice guidelines are explicit statements that guide patient evaluation and treatment. The development of these guidelines for the management of motor speech disorders was initiated by the Academy of Neurologic Communication Disorders and Sciences (ANCDS). The complete report for management suggestions specific to respiratory/phonatory dysfunction can be found elsewhere (Spencer, Yorkston, Duffy et al., 2002; <http://www.ancds.duq.edu/guidelines.html>).

One impetus of this work was to provide a flowchart that would assist the clinical decision-making process by placing management options in the context of the support available for those options. The support for a particular management technique may come from the dysarthria intervention literature or from expert opinion. Evidence-based support from the research literature implies that positive outcomes have been reported for a minimum of one intervention study for at least one person with dysarthria. Conversely, support from expert opinion suggests that although data-based evidence was not available for that particular technique, support was derived from the training or experience of the expert. These techniques are acknowledged in textbooks or review articles by experts in the field of speech-language pathology. The delineation of the types of support for specific management strategies is not intended to dictate or limit management options. The heterogeneity of populations with respiratory/phonatory dysfunction from dysarthria argues for thoughtful clinical

decision making based on myriad influences (e.g., medical factors, cognitive concerns, personality/motivation issues, environmental barriers, level of familial support, financial concerns, etc.). Rather, this information is intended to offer guidance for clinicians and researchers who are interested in the existence and nature of support for management options. Furthermore, this review serves to identify those areas of management that lack empirical support and might benefit from attention by clinical researchers.

The flowchart is divided into an assessment section (A1–A3) and a management section (C–H). The assessment section highlights evaluation strategies specific to respiratory/phonatory dysfunction. Unless otherwise indicated, this information is based on expert opinion only. The management section identifies all known behavioral treatments for respiratory/phonatory dysfunction as identified in the literature on dysarthria. Both the assessment and the management sections are based on a theoretical and practical separation of treatment strategies into three paths that address (a) decreased respiratory support, (b) decreased respiratory/phonatory coordination and control, and (c) reduced phonatory function. If respiratory/phonatory functioning is impaired, it is likely to stem at least in part from one (or more) of these three areas. Despite the natural coupling of the respiratory and phonatory systems, this theoretical separation encourages the clinician to approach treatment methodically.

Decreased respiratory support is broadly defined as insufficient breath support for speech. Lack of appropriate breath support would likely manifest as reduced loudness, short phrases, and reduced pitch and loudness variability. This constellation of symptoms from weakened respiratory drive is most often found in people with flaccid dysarthria, but can result from other forms and combinations of dysarthria. Conversely, *decreased respiratory/phonatory coordination and control* implies adequate respiratory support but difficulty with the synchronization of breathing and speaking. Speech symptoms might include excess loudness variations, inappropriate silences, harsh voice quality, inappropriate breath patterning, transient breathiness, voice stoppages, and so on. Deviant speech dimensions of this nature most often stem from the abnormal, involuntary movements associated with the hyperkinetic dysarthrias or from the inaccurate timing and range of movement associated with ataxic dysarthria. It is also possible for clients with diffuse brain injury to evidence both decreased support and decreased coordination/control.

Finally, *reduced phonatory function* refers to hypoadduction or hyperadduction of the vocal folds. Hypoadduction of the vocal folds often results in breathiness, hoarseness, reduced loudness, and so forth, and is most often associated with flaccid and hypokinetic dysarthrias. Hyperadduction of the vocal folds typically manifests as harsh/strained vocal quality, slow rate of speech, low pitch, and so forth. It is typical of people with spastic and hyperkinetic dysarthrias. Reduced phonatory function can, and often will, overlap with decreased respiratory support and decreased coordination/control. The circled letters on the flowchart (Figure 1) refer the reader to the corresponding part of the text.¹

A. ASSESSMENT OF RESPIRATORY/PHONATORY FUNCTION

As illustrated in the flowchart, the assessment of respiratory/phonatory function comprises three main areas: gathering of history and referral information (A1), assessment of motor speech characteristics (A2), and the physical examination (A3).

A1. History and Referral Information

Aside from the customary information obtained during the initial assessment, specific attention should be paid to the patient's presenting complaints, as they may provide the initial evidence of respiratory or phonatory involvement. Examples of complaints that may be particularly revealing are

- Fatigue during speech (Duffy, 1995; Yorkston et al., 1999)
- Shortness of breath at rest, during exertion, or during speech (Duffy, 1995; Yorkston et al., 1999)
- Ability to say only a few words per breath (Yorkston et al., 1999)
- Inability to increase loudness or shout (Yorkston et al., 1999)
- A weakened cough (Smeltzer et al., 1992)
- Effortful speaking; feeling as if speaking against resistance (Duffy, 1995)

A2. Motor Speech Examination

The assessment of speech characteristics also can provide a window into the nature and existence of respiratory and/or phonatory subsystem involvement. As outlined by Yorkston et al. (1999), the adequacy of *respiratory functioning* for speech can be determined, in part, by the perceptual evaluation of loudness and breath patterning. Inadequate loudness and improper control of loudness, as well as abnormal patterning of inhalation and exhalation during speech, may serve as indicators of impaired respiratory support, coordination, or both. The following are specific observations to make regarding loudness and breath patterning while the patient is speaking (Yorkston et al., 1999).

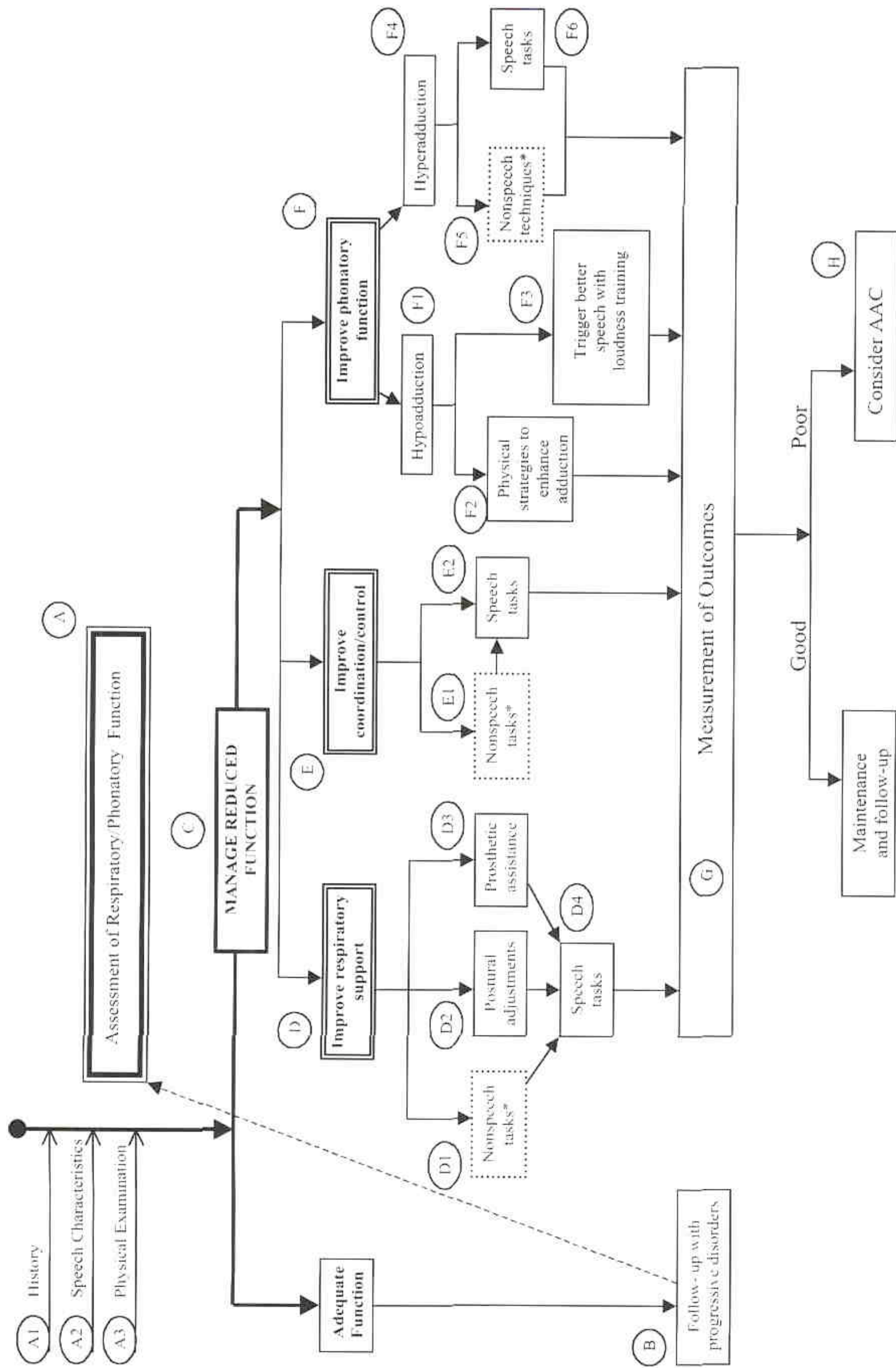
Observations of the Speaker's Loudness

- Appropriateness of overall loudness level
- Consistency of appropriate loudness level
- Maintenance of loudness over the course of a single breath group or over the course of extended speech
- Ability to increase loudness
- Ability to speak quietly
- Ability to emphasize words in a sentence by increasing loudness

Observations of the Speaker's Breath Patterning

- Ability to demonstrate the normal pattern of quick inhalation followed by prolonged exhalation
- Ability to inhale to appropriate lung volume levels at the beginning of the respiratory cycle (this, however, may be difficult to judge perceptually; Chenery, 1998)
- Ability to initiate speech at normal points in the respiratory cycle
- Appropriateness of the frequency, smoothness, duration, and syntactic location of inhalation during ongoing speech
- Absence of sudden, forced inspiratory/expiratory sighs
- Absence of exaggerated respiratory maneuvers (e.g., excessive elevation of the shoulders) during speech

¹Understanding normal respiratory and phonatory function is a requisite foundation for the management of individuals with dysarthria. A review of the anatomical and physiological underpinnings of the speaking and breathing apparatus is beyond the scope of this article. For a complete overview of normal respiration for speech, readers are referred to sources such as Hixon (1987), Warren (1996), or Weismer (1985).



* Please refer to text for qualifications for using nonspeech techniques.

Figure 1. Flow chart of treatment options for respiratory/phonatory impairment in speakers with dysarthria.

The adequacy of *phonatory functioning* can initially be described by a voice quality rating. There is not a generally accepted method of evaluating speech quality; however, for most purposes, a simple voice rating scale for dimensions such as hoarseness, breathiness, roughness, and pitch level will suffice (Kent, Kent, Duffy, & Weismer, 1998). Specific voice characteristics such as phonatory instability, tremor, inability to vary pitch, excessive fluctuations of pitch, inhalatory stridor, and wet phonation should be considered for a more thorough depiction of the phonatory abnormalities associated with the dysarthrias.

A3. Physical Examination

The final component of an assessment of respiratory/phonatory functioning is the (nonspeech) physical examination of the speech mechanism, which should be conducted if there are concerns of respiratory or phonatory abnormalities. At a minimum, observations can be made of the patient during quiet breathing. These observations, drawn from Duffy (1995) unless otherwise indicated, may provide insight into the presence of respiratory/phonatory impairment, and whether dysfunction stems from weakness, incoordination, involuntary movements, and/or maladaptive strategies. They include

- Abnormal posture
- Rapid, shallow or labored breathing
- Limited range of abdominal and thoracic movements
- Shoulder movements, neck extension, neck retraction, or flaring of the nares on inhalation
- Irregular breathing rate; abrupt movements which alter normal cyclical breathing
- Paradoxical movements of the thorax and abdomen, that is, the thorax expands while the abdomen retracts, or vice versa
- Audible breathy inspiration, inhalatory stridor, or an audible grunt at the end of expiration (Chenery, 1998)

A more thorough examination of the respiratory/phonatory system may be appropriate if abnormalities are noted during the assessment of speech characteristics (e.g., loudness levels, breath patterning, and vocal quality) or during observations of quiet breathing. A description of this assessment will be organized into the three major areas of dysfunction discussed previously: decreased respiratory support, reduced respiratory/phonatory coordination and control, and compromised laryngeal functioning. Each of these areas will be discussed in terms of the evaluative strategies one might employ for a more comprehensive assessment. Strategies will be based on "clinical screening" methods and instrumental techniques, although the lack of widespread clinical use of instrumental measures is recognized (Coelho, Gracco, Fourakis, Rossetti, & Oshima, 1994).²

Comprehensive Physical Examination of a Suspected Decrease in Respiratory Support

Table 1 highlights strategies for assessing the adequacy of respiratory support for speech using clinical screening methods and more sophisticated instrumental techniques. Decreased respiratory support would be especially prominent in patients with lower motor neuron involvement (i.e., flaccid dysarthria), but can contribute to the speech production difficulties of speakers with many forms of dysarthria. Clinical screening methods provide only a general gauge of respiratory functioning, but may be the only available clinical testing method in many settings. Instrumental measures are employed by some to obtain more precise information regarding respiratory drive and capacity and to objectify perceptual observations (Thompson-Ward & Murdoch, 1998). However, instrumental measures often are unavailable or have been obtained previously as part of the medical examination for patients with apparent respiratory compromise. Moreover, research is needed to establish the relationship between perceptual and instrumental measures and to determine whether one form of measurement is predictive of the other.

²For an exceptionally comprehensive physical examination protocol for people suspected of having a speech breathing disorder, the reader is referred to protocols developed by Hixon and Hoit (1998, 1999, 2000). The degree of abnormality of the diaphragm (1998), abdominal wall (1999), and rib cage wall (2000) can be thoroughly assessed using a 5-point scale (worksheets included) while the patient performs exercises designed to elicit specific clinical observations. Additionally, Redstone (1991) provides guidelines on assessing respiration in children with multiple disabilities and subsequent abnormal muscle tone.

TABLE 1. Clinical screening and instrumental methods for assessing respiratory support for speech.

| Clinical Screening | | |
|---|--|--|
| Method | Purpose | Considerations |
| Simple water glass manometer (Hixon et al., 1982) | Provides a gross measure of the minimum and maximum pressure-generating capabilities for speech production | Sustaining a pressure of 5cm H ₂ O for 5 sec suggests sufficient respiratory support for speech (Netsell & Hixon, 1978). Criterion of 10cm H ₂ O for 10 sec needed for some patients (see Netsell, 1998). |
| Hand-held respirometer | Used as an economical device for gathering data on vital capacity (Beckett, 1971) | Vital capacity (and other pulmonary function measures) is limited in its ability to predict impaired speech function. |
| Sharpness of patient's cough | When contrasted with the glottal coup, may help separate respiratory from laryngeal contributions to respiratory drive (Duffy, 1995) | Very gross indicator of respiratory support. However, production of a strong cough entails considerable respiratory and vocal fold adduction (Yorkston et al., 1999). |
| Sustained phonation time | Provides a general estimate of respiratory/phonatory capacity | Numerous caveats for use (Kent, 1997; Robin et al., 1997; Solomon, Garlitz, & Milbrath, 2000). |
| Sustained phonation with changes in loudness | Estimates modulations of respiratory drive | Same as above. However, abrupt loudness increases suggest ability to volitionally raise subglottal air pressure. |
| Instrumental Measures | | |
| Parameters* | Method | Considerations |
| Subglottal air pressure | 1. Air pressure transducer with a pneumotachometer 2. U-tube manometer with a leak to simulate laryngeal resistance (Netsell & Hixon, 1978) | Subglottal air pressure is estimated by measuring intraoral air pressure. However, reduced air pressures are not always indicative of respiratory weakness; it is possible that impairment in other areas of the speech mechanism may contribute to reduced air pressure values (Yorkston et al., 1999). |
| Lung volume | 1. Spirometer 2. Pneumotachograph 3. Measuring motions of the chest wall and calibrating this to known volume measures | Spirometric assessments allow measurement of vital capacity, reserve volumes, etc., which can be compared to normative values. Limitations include use of physical encumbrances that can alter respiratory function and inability to detect small, rapid volume changes like those that occur during speech (Thompson-Ward & Murdoch, 1998). |
| Airflow | 1. Spirometer 2. Pneumotachograph 3. Chest-wall kinematics (can infer airflow volume changes) | Same as above. |
| Chest-wall shape | Respiratory inductive plethysmography or magnetometry (kinematics) | Kinematic measures allow the inference of airflow volume changes from rib cage and abdominal displacements. |

*The conceptual framework for these respiratory parameters was developed by Hixon (e.g., Hixon, 1987, 1993).

Comprehensive Physical Examination of a Suspected Decrease in Respiratory/Phonatory Coordination or Control

Reduced respiratory/phonatory coordination may be evidenced most often in people with ataxic and hyperkinetic dysarthrias, including children with cerebral palsy. The following are assessment strategies, divided into clinical screening and instrumental techniques, that can be used to assess the coordination of breathing and speech.

Clinical Screening. Screening methods for determining incoordination are based largely on physical examination and breath-patterning observations during connected speech (outlined previously). Certain behaviors may also reflect reduced support and are identified as such.

- Irregular breathing rate; abrupt movements that alter normal cyclical breathing
- Paradoxical movements of the thorax and abdomen, that is, the thorax expands while the abdomen retracts, or vice versa (Yorkston et al., 1999)
- Absence of the normal pattern of quick inhalation followed by prolonged exhalation
- Initiation of speaking at atypical points in the respiratory cycle
- Interruption of speech from sudden, forced inspiratory/expiratory sighs
- Exaggerated respiratory maneuvers (e.g., *excessive elevation of the shoulders*) during speech (may also reflect reduced support)
- Running out of air before inhaling (may also reflect reduced support)
- Breathing at syntactically inappropriate locations in the utterance (may also reflect reduced support)

Additionally, speech-language pathologists can feel for gross changes in chest wall shape by placing one hand on the abdomen and the other on the rib cage (Robin, Solomon, Moon, & Folkins, 1997; Yorkston et al., 1999). As noted by Yorkston and colleagues, however, this method is informal and does not yield precise or objective measures of shape, timing or respiratory volume.

Instrumental Measures. If available and appropriate, instrumental assessment of respiratory/phonatory coordination would likely involve kinematic methods. Kinematic measures are based fre-

quently on magnetometer systems or respiratory inductive plethysmography (Respirtrace) and can provide objective information regarding respiratory shape. Use of this instrumentation allows the speech-language pathologist to substantiate observations of inconsistent lung volume levels (i.e., the patient initiates speech at varying lung volume levels), inappropriate lung volume levels (i.e., the patient initiates speech below the desired lung volume level), and excessive lung volume levels (i.e., the patient initiates speech above the desired lung volume level) (Yorkston et al., 1999). Additionally, McHenry and Minton (1998) addressed specific factors to consider when instrumentally evaluating speech breathing in speakers who are difficult to assess due to physiologic or cognitive problems.

Comprehensive Physical Examination of Suspected Phonatory Impairment

A formal laryngeal assessment should be conducted when structural pathology or lesions of the vagus nerve are a possibility (Duffy, 1995) or prior to intensive voice therapy, such as the Lee Silverman Voice Treatment program (Ramig, Countryman, Fox, & Sapir, 2002). Tables 2 and 3 provide strategies for the evaluation of phonatory function using clinical screening and instrumental techniques. Phonatory dysfunction can manifest from all forms of dysarthria. However, hypoadduction of the vocal folds most often stems from flaccid and hypokinetic dysarthria, whereas hyperadduction frequently occurs in speakers with spastic and hyperkinetic dysarthria.

B. FOLLOW-UP WITH PROGRESSIVE DISORDERS

When assessment results suggest adequate respiratory/phonatory functioning for the needs and desires of the patient, the management of those subsystems is typically unnecessary or discontinued. However, there are several progressive disorders for which the onset of respiratory and/or phonatory difficulties is likely during the course of the disease. As illustrated by component B in the flowchart, patients with diseases such as amyotrophic lateral sclerosis (ALS), Huntington disease, Parkinson disease, multiple sclerosis, and Friedreich's ataxia should be monitored by the treatment team on a routine basis for the emergence of respiratory/phonatory decline. Monitoring the respiratory status of individuals with ALS, in particular, is crit-

TABLE 2. Clinical screening methods for assessing phonatory function.

| Clinical Screening | | |
|--|---|--|
| Method | Purpose | Considerations |
| Sustained phonation time | Global assessment of phonatory capacity | Numerous caveats for use (Kent, 1997; Robin et al., 1997; Solomon 2000). Maximum phonation times are, however, decreased when vocal fold bowing, weakness/paralysis, etc., prevent complete closure (Robin et al., 1997). |
| S:Z ratio | Gross method for differentiating respiratory from phonatory dysfunction | Ratios greater than one are cautiously interpreted as involvement of the larynx, whereas reductions of both /s/ and /z/ tend to implicate the respiratory system. However, reductions might stem from deficits elsewhere in the system, such as ineffective vocal tract constriction, thus proving problematic for subsystem isolation (Robin et al., 1997). |
| Laryngeal diadochokinesis (repeating a vowel as rapidly as possible) | May serve as an index of the neural integrity of the phonatory system (Verdolini, 1994) | Strong, consistent productions are indicative of normal functioning. Verdolini (1994) recommended obtaining measures of rate, loudness, and clarity over time. |
| Systematically vary pitch | General indicator of phonatory range and control (Kent, 1997) | Laryngeal control also can be roughly estimated by evaluating the speaker's ability to produce voiced versus voiceless contrasts (Yorkston et al., 1999). |
| Cough and glottal coup | Gross integrity of adduction can be inferred from sharpness | A weak coup but normal cough tends to be associated with laryngeal weakness (Duffy, 1995). |

TABLE 3. Instrumental methods for assessing phonatory function.

| Instrumental Measures* | |
|--|--|
| Direct Methods | Indirect Methods |
| Endoscopy/Laryngoscopy Inserted through the oral cavity; allows observation of vocal folds during phonation of vowels | Photoglottography Indirect technique; light transmitted to photosensor should be proportional to the glottal opening |
| Nasoendoscopy Oral cavity not obstructed; direct observation of laryngeal function can be obtained during normal speech production | Electroglottography Popular indirect method; provides information on the vibratory patterns of the vocal folds |
| Videostroboscopy Strobe light source allows "slow-motion" viewing of vocal folds through the entire glottal cycle | Spectrographic/Acoustic Analyses Allows examination of fundamental frequency, frequency range, laryngeal perturbation measures, etc. |
| High-speed Photography Allows for finer details of glottal movement to be observed; cost may be prohibitive | Phonatory Function Analysers Can provide detailed information on airflow, air pressures, acoustic output, etc. |
| Indirect Mirror Laryngoscopy Common way to view vocal fold activity; allows observation of structural abnormalities | |

*See Thompson-Ward & Murdoch (1998) for further description.

ical in the staging of interventions; failure of the respiratory system is the most common cause of death in this disease (Yorkston, Strand, & Miller, 1996). The frequency of the screenings would be contingent on numerous factors, including the rapidity with which the disease is progressing and the level of concern of the patient.

C. MANAGEMENT OF REDUCED FUNCTION

If the results of the respiratory/phonatory assessment indicate reduced function, decisions must subsequently be made regarding treatment candidacy and treatment focus. As discussed, the symptoms of respiratory/phonatory impairment may be categorized as reductions in respiratory support, respiratory/phonatory coordination and control, and/or phonatory functioning. These three areas will serve as an organizing framework for clinical decision making in the management of the respiratory/phonatory aspects of speech. Regardless of the specific area of impairment, there are general principles of intervention that should be understood prior to treatment implementation. Several sources are available that discuss the broad issues, concepts, and techniques related to management of people with dysarthria (Duffy, 1995; Rosenbek & LaPointe, 1985; Yorkston, Beukelman, & Bell, 1988). One such issue is the potential influence of the principles of motor learning on decisions regarding treatment structure and execution. Much research is available on the benefits of using motor learning principles when training limb movements (Schmidt & Lee, 1999). Research relevant to speech production is sparse. However, evidence is beginning to emerge on the beneficial effects of using principles of motor learning as related to the training of speech (Adams & Page, 2000; Schulz, Sulc, Leon, & Gilligan, 2000), and voice (Ferrand, 1995; Steinhauer & Grayhack, 2000), as well as designing effective intervention strategies (Ramig, Pawlas, & Countryman, 1995). At present, this research provides a basis for judicious use of the principles of motor learning in treatment for motor speech disorders.

For each treatment path (D–F) in the flowchart, information is provided regarding those treatment techniques that have evidence-based support from at least one study in the dysarthria intervention literature. Additionally, techniques that do not have empirically demonstrated efficacy, but have

support from experts in the field of speech-language pathology, are discussed. Finally, treatment techniques are highlighted that lack current support from intervention research or expert opinion.

D. IMPROVING RESPIRATORY SUPPORT

Component D of the flowchart highlights treatment strategies for speakers with inadequate breath support for speech. These strategies are designed to improve respiratory drive and would be used most often with patients with severe flaccid dysarthria. Depending on the abilities, needs, and stimulability of an individual patient, clinicians may opt to use one or more of the following treatment approaches: nonspeech tasks (D1), postural adjustments (D2), prosthetic assistance (D3), and speech tasks (D4).

D1. Nonspeech Tasks

Generally, intervention focusing on nonspeech activities is limited to speakers unable to generate adequate subglottal air pressure to support phonation. Nonspeech tasks are typically unnecessary and inappropriate for patients who can perform speech exercises to accomplish the treatment goal (Duffy, 1995). However, for patients who are severely impaired, nonspeech respiratory tasks that isolate breathing may serve as an essential building block for future speech production. It is important to note, however, that the generalization of nonspeech activities to speech production is predictably challenging (Gerratt, Till, Rosenbek, Wertz, & Boysen, 1991).

Historically, therapy targeting the strengthening of respiratory muscles has been reported most frequently for children with cerebral palsy. Early therapy approaches for this population consisted of techniques such as blowing out matches; blowing balloons, bubbles, harmonicas, and feathers; placing a flat sandbag on the supine child's abdomen to increase rib excursions (Blumberg, 1955); applying pressure with thumbs by pushing up and under the rib cage to stimulate the diaphragm; "vibrating" on the patient's diaphragm, ribs, or spine; placing a cube of ice above the diaphragm to provide proprioceptive stimuli (Hoberman & Hoberman, 1960); and electrical stimulation (Jones, Hardy, & Shipton, 1963). Many of these early studies demonstrated some improvement in vital capacity, but they suffered from a lack of speech outcome mea-

tures (Solomon & Charron, 1998) and methodological rigor.

In appropriate cases, there are potential benefits from direct (nonspeech) focus on the respiratory subsystem. Increasing vital capacity and endurance for breathing may result in the ability to produce more syllables on one breath and talk for longer periods of time, assuming laryngeal, velopharyngeal, and upper articulator valving are adequate (Solomon & Charron, 1998). The following techniques have evidence-based support from the dysarthria intervention literature for improving respiratory support.

- Breathing against resistance through a simple water manometer or blow bottle (Daniel-Whitney, 1989; Hixon, Hawley, & Wilson, 1982; Netsell & Daniel, 1979; Workinger & Netsell, 1992), or a resistive mask (Cerny, Panzarella, & Stathopoulos, 1997)
- Pushing and pulling techniques (Workinger & Netsell, 1992)
- Biofeedback of chest wall movement to help increase abdominal movement and overall lung volume (Thompson-Ward, Murdoch, & Stokes, 1997)

There are several nonspeech tasks that are not substantiated by dysarthria intervention research, but are instead supported by expert opinion. Some of these techniques arise from a similar physiologic rationale for improving respiratory support as the previous methods. They include

- Maximum inhalation and exhalation tasks (Ramig & Dromey, 1996; Ramig et al., 1995)³
- Controlled exhalation tasks (Brookshire, 1992; Murry & Woodson, 1995; Ramig & Dromey, 1996; Ramig et al., 1995)
- Breathing against resistance through pursed lips (Solomon & Charron, 1998)
- Using an air pressure transducer with feedback from an oscilloscope or computer screen
- Sustaining phonation with feedback from Visipitch or the VU meter on a tape recorder.

Hixon, Putman, and Sharpe (1983) provided information regarding *compensatory breathing strategies*

(neck breathing and glossopharyngeal breathing) for patients with flaccid paralysis of the rib cage, diaphragm, and abdomen. As Duffy (1995) noted, however, these strategies may be limited to patients with isolated respiratory impairments, and they should be cleared by a physician knowledgeable about pulmonary function prior to implementation.

D2. Postural Adjustments

Body positioning can have a marked influence on respiratory support for speech as the behavior of the breathing apparatus differs substantially depending on body position (Hoit, 1995). Thus, postural adjustments or correct positioning, particularly for patients who require a wheelchair, can be a simple yet effective method for improving respiratory drive for speech (Horton, Murdoch, Theodoros, & Thompson, 1997). The nature of the postural adjustments will depend on many factors, including the degree of the patient's inspiratory versus expiratory difficulty, the level of the patient's voluntary motor control, and concomitant medical/physical difficulties. At present, the efficacy of postural adjustments to manage respiratory/phonatory dysfunction is largely unknown. Postural manipulations have been used as a relatively inconsequential part of larger treatment programs with unknown influences on the outcome measures (e.g., Murdoch, Pitt, Theodoros, & Ward, 1999) and have been shown to have a negligible effect on the lung function measures of children with athetoid and quadriplegic spastic cerebral palsy (e.g., Hardy, 1964). Generally, guidance for intervention in this area stems primarily from expert opinion only.

Patients with significant *inspiratory problems* may perform best in the upright position because gravity can assist in lowering the diaphragm into the abdomen on inspiration (Duffy, 1995). Inspiratory difficulties are often encountered, for example, in patients with ALS and obstructive lung disease (Yorkston et al., 1999). By extension, patients with Parkinson disease may experience limited respiratory support due, in part, to their characteristic hunched-forward position. Facilitating an upright position in these patients may optimize their speech breathing.

Expiratory difficulties are encountered, for example, in patients with traumatic brain injury

³Ramig and colleagues have demonstrated greater treatment effects for a combined respiratory/phonatory treatment approach versus a respiratory-only treatment in persons with Parkinson disease.

(TBI), spinal cord injury, and multiple sclerosis. Patients with greater expiratory than inspiratory difficulty for speech may benefit from the supine position because gravity and abdominal contents help to push the diaphragm into the thoracic cavity to assist expiration (Netsell & Rosenbek, 1985). Appropriate positioning for adequate physiologic support can be accomplished using adjustable beds and wheelchairs and chairs with adjustable backs (Yorkston et al., 1999). Supine positioning has also been used therapeutically with patients with cerebral palsy to minimize effects of spasticity (Solomon & Charron, 1998). The trade-off of supine positioning, however, is that inspiratory ability will be diminished. Moreover, the use of positions other than upright to train speech breathing has been criticized. According to Hoit (1995), the change in body position from supine to upright dramatically alters the mechanical characteristics of the respiratory system and impedes generalization across body positions.

The long history of position modifications for children with cerebral palsy (e.g., head and trunk control and alignment; sitting postures) has been motivated, in part, by the neurodevelopmental treatment (NDT) framework (Redstone, 1991). However, reviews of the literature suggest that efficacy of NDT on breathing or speech has not been established (Solomon & Charron, 1998).

D3. Prosthetic Assistance

In rare cases, prosthetic devices may be necessary to supplement expiratory forces during speech. The two primary forms of prosthetic assistance are expiratory boards/paddles and abdominal trussing. These types of assistive devices may be evaluated in consultation with a physical therapist.

Expiratory boards or paddles provide a stationary object for the patient to lean into while speaking, thus increasing expiratory force. Clinicians can determine candidacy for an expiratory board by placing a hand on the patient's abdomen and applying varying amounts of pressure during inhalatory and exhalatory portions of the respiratory cycle for speech (Rosenbek, 1984). As discussed by Rosenbek, demonstrable improvement in overall loudness or loudness patterns suggests that a

board/paddle may be appropriate as a short-term treatment while physiologic recovery is occurring, or permanently if a speaker fails to regain neuromotor control. Patients requiring the assistance of an expiratory board, however, commonly lack adequate trunk strength or balance to use it properly (Yorkston et al., 1999). An alternative approach that may benefit some patients with adequate arm strength is to push in on the abdomen with one hand during expiration (Duffy, 1995). The use of expiratory boards/paddles is supported by expert opinion only and is not substantiated by intervention research.

For patients who do not have the upper torso motor control to use an expiratory board, *abdominal trussing* may be considered. Trussing is the process of fixing the abdomen inward relative to rest position, and includes the use of abdominal binders or corsets, abdominal wraps, and pneumobelts (Watson & Hixon, 2001). Abdominal trussing is used to help support weak abdominal muscles, enhance posture, and enable more efficient speech breathing. Ideal candidates for this form of treatment typically have intact diaphragmatic function but weak expiratory muscles, which tends to occur more often in patients with spinal cord injury (Yorkston et al., 1999) and some children with cerebral palsy (Solomon & Charron, 1998). The risk of abdominal binding, however, is that it may restrict inspiration and cause pneumonia (Rosenbek & LaPointe, 1985), and it is ineffective and potentially dangerous for patients with inspiratory weakness (Yorkston et al., 1999). As such, medical approval and supervision are essential when abdominal trussing techniques are used, and extended use should be limited (Duffy, 1995). Evidence-based support for this intervention is available and includes a case study of a patient with severe dysarthria (Simpson, Till & Goff, 1988) and a study of three men with spinal cord injury (Watson & Hixon, 2001).¹

D4. Speech Tasks

Improvements in respiratory support are ideally targeted during actual speech production. The focus of these treatment approaches varies, but generally can be grouped as modification of the inhalatory/exhalatory pattern or biofeedback.

¹The focal respiratory impairment associated with spinal cord injury is clearly germane to the discussion of respiratory/phonatory impairment in dysarthria. However, the unique and complex issues inherent to the management of spinal cord injury warrant complete coverage in a separate Practice Guidelines module. Thus, the discussion of respiratory impairment from spinal cord injury in this particular module is limited to illustrative clinical examples.

Manipulations of breathing patterns during speech production can provide a means of improving respiratory support, although the suggested methods are supported by expert opinion only. Some patients may simply need to practice inhaling more deeply or using more force when exhaling during speech (Hammen & Yorkston, 1994; Ramig, 1986; Ramig et al., 1995). As deeper inhalations generate more forceful elastic recoil of the lungs, patients with weak respiratory systems may have excessive loudness bursts or rapid air wastage if the higher expiratory pressures are unchecked during exhalation (Duffy, 1995). Netsell (1998) noted the importance of maintaining stable pressures throughout the breath group and has described a treatment strategy for producing stable subglottal air pressure. "Inspiratory checking" (Netsell, 1992, 1995) is performed by asking the patient to inhale to approximately 50% of maximum capacity and then to "let the air out slowly" when talking. By extension, patients may also practice sustaining isolated sounds for 5 seconds while keeping intensity and quality constant (Rosenbek & LaPointe, 1985). Another method for enhancing respiratory support for speech is abdominal or diaphragmatic breathing, which affords the greatest lung volumes and subsequently increases abdominal contributions during speech (Thompson-Ward et al., 1997).

Various forms of *biofeedback* can be used to allow patients to gauge both respiratory force and ability to maintain consistent subglottal air pressure. Output from air pressure transducers can be displayed on an oscilloscope for patients to work toward the targeted air pressure levels. Yorkston et al. (1999) reported using this method with patients with TBI who demonstrated difficulty maintaining consistent air pressure levels or who produced excessively large air pressure values during speech. Once respiratory support for sustained phonation is established, speech stimuli can progress from speech-like items, such as repetition of syllables, to utterances of increasing length. Utterances should be constructed with ample tokens of the phoneme /p/ to allow adequate monitoring of air pressure (Yorkston et al., 1999). Although not as precise an outcome measure, systems such as VisiPitch or even the VU meter on a tape recorder can be used to target specific loudness levels during speech production or sustained phonation. Numerous evidence-based studies have reported improvement of various aspects of respiratory support from biofeedback therapy (McNamara, 1983; Murdoch et al., 1999; Ramig & Dromey, 1996; Simpson, Till, & Goff,

1988; Thompson-Ward et al., 1997). It should be noted, however, that candidacy for biofeedback therapy may be influenced by the patient's level of stimulability. Volin (1998), in a study of biofeedback for respiratory rate control, found that individuals who are likely to benefit from biofeedback include those whose stimulability levels are in the low to middle ranges, that is, subjects with relatively poor response to initial training. Patients with high levels of stimulability actually showed a large decrement in performance after receiving biofeedback training.

As indicated previously, generalization will be enhanced considerably if the tasks outlined for nonspeech, postural, and prosthetic treatment approaches incorporate speech stimuli as soon as possible. For instance, the pushing/pulling techniques described in the nonspeech tasks section may be employed initially, with the patient producing only breath or undifferentiated vowels. Speech stimuli should then progress in a timely manner to differentiated vowels and syllables and should, for appropriate patients, culminate with connected speech. Table 4 summarizes the nature of the support for the various treatments for improving respiratory drive for speech.

E. IMPROVING COORDINATION/CONTROL

Component E of the flowchart highlights treatment options for speakers who have difficulty coordinating their respiratory and phonatory systems during speech. These treatment techniques are designed to stabilize respiratory/phonatory patterns during speech and often would be used with persons with ataxic or involuntary movements (i.e., speakers with ataxic or hyperkinetic dysarthrias), but may be appropriate for other forms of dysarthria.

E1. Nonspeech Tasks

Many of the nonspeech tasks for improving respiratory coordination and control derived from the treatment of children with cerebral palsy. Blumberg (1955) reported using nonspeech techniques such as matching the rate of respiration to the ticking of a metronome to develop regular breathing rate and rhythm. More recently, Solomon and Charron (1998) identified nonspeech strategies for improving the respiratory coordination of children with cerebral palsy by

TABLE 4. Summary of techniques and corresponding levels of support for improving respiratory drive for speech.

| <i>Treatment Focus</i> | <i>Treatment Technique</i> | Evidence-Based Support | Expert Opinion Only | No Support |
|------------------------------|--|-------------------------------|----------------------------|-------------------|
| Nonspeech Tasks | Breathing against resistance through a water manometer, blow bottle, or resistive mask | ✓ | | |
| | Pushing and pulling techniques | ✓ | | |
| | Biofeedback of chest wall movement | ✓ | | |
| | Maximum inhalation and exhalation tasks | | ✓ | |
| | Controlled exhalation tasks | | ✓ | |
| | Breathing against resistance through pursed lips | | ✓ | |
| | Using an air pressure transducer with feedback from an oscilloscope/computer screen | | ✓ | |
| | Sustaining phonation with feedback from VisiPitch or the VU meter of a tape recorder | | ✓ | |
| | Blowing balloons, bubbles, feathers, etc. | | | ✓ |
| | Applying pressure/vibration to <i>diaphragm, ribs, etc.</i> | | | ✓ |
| | Applying ice to diaphragm | | | ✓ |
| | Electrical stimulation | | | ✓ |
| Postural Adjustments | Upright posture for people with inspiratory problems | | ✓ | |
| | Supine position for people with expiratory difficulties | | ✓ | |
| | Adaptive seating systems for people with expiratory difficulty | | ✓ | |
| | Neurodevelopmental Treatment | | | ✓ |
| Prosthetic Assistance | Expiratory boards/paddles | | ✓ | |
| | Push in abdomen with one hand during expiration | | ✓ | |
| | Abdominal trussing | ✓ | | |
| Speech Tasks | Modification of the inhalatory/exhalatory pattern | | ✓ | |
| | Inspiratory checking | | ✓ | |
| | Biofeedback of targeted air pressure levels | ✓ | | |

- Rehearsing a speech-like breathing pattern (*i.e., quick inspirations and slow, controlled expirations*)
- Implementing “inspiratory checking” (Netsell, 1992) without accompanying speech (if it is

- problematic for the patient to speak on controlled exhalations)
- Facilitating inspiratory coordination and speed through sniffing or exhalatory coordination through blowing

- Practicing switching between inspiration and expiration; the speed of the task can eventually be increased to resemble panting⁵

These techniques are not restricted to patients with dysarthria from cerebral palsy; similar strategies have been suggested for use with other patient populations, such as individuals with spastic dysarthria (Thompson, Murdoch, & Theodoros, 1997) and mixed dysarthria (Murdoch et al., 1999). Murdoch et al. (1999), in the one evidence-based intervention study to examine these techniques, implemented nonspeech tasks as part of the respiratory treatment for a child with persistent dysarthria following severe TBI. The caveats regarding nonspeech tasks outlined in the previous discussion of respiratory support treatment apply here as well. Specifically, nonspeech tasks are often inappropriate for patients who can perform speech exercises and should be modified to include speech stimuli as soon as possible to promote generalization to speech production.

E2. Speech Tasks

With the exception of a study by Thompson-Ward et al. (1997), the use of speech tasks to improve respiratory/phonatory coordination and control is supported more by expert opinion than evidence-based research. Thompson-Ward and colleagues provided *feedback* on chest wall movement and phonation to train a speaker with spastic dysarthria to learn to continue phonation throughout the breath stream. In general, patients who experience difficulty with respiratory/phonatory coordination or control may benefit from improved awareness of the speech-breathing pattern, that is, quick inspiration followed by prolonged exhalation during speech production. Patients may need to modify how much air is inhaled prior to speaking and may need to learn how to control air use during speaking. Teaching patients to evaluate and monitor loudness levels during speech may be an important first step in recognizing inappropriate loudness or loudness changes (Rosenbek, 1984). Instrumental feedback from RespiTrace and magnetometers, for example, also can be particularly useful for demonstrating the desired breathing pattern. If necessary, the clinician can place one or both hands on the patient's abdomen and combine pressing movements

with instruction about getting to the "right size" during inhalation/exhalation (Rosenbek, 1984). The speech stimuli for these exercises can range from syllables or simple words to complex sentences; stimuli of graded difficulty should be employed to encourage respiratory/phonatory control over progressively more propositional utterances. By extension, speakers can be instructed to use *optimal breath groups* (Linebaugh, 1983), that is, the number of syllables that can be produced comfortably on one breath. Once a baseline is established, the targeted length of phrases and sentences uttered in a single breath group can be gradually increased to encourage respiratory control. As discussed in the respiratory support section, *inspiratory checking* is a technique for controlling the flow of air through the larynx by countering the elastic recoil forces of the respiratory system (Netsell, 1992). This strategy may prove useful for speakers who release excessive airflow through the larynx when they speak (Netsell, 1995). Yorkston et al. (1999) provided suggestions regarding the training of *respiratory flexibility*. Normal speakers will vary their inhalation depth depending on the length and volume of the intended utterance. If the demonstrated speech-breathing pattern of the patient suggests an inability to vary depth of inhalation, the general rules that govern respiratory performance during speech can be reviewed, followed by practice reading cued and uncued conversational scripts with and without a conversational partner.

Candidates for these treatment strategies include patients who

- Initiate speech at variable points in the respiratory cycle and need more consistent inspiratory control (Duffy, 1995)
- Initiate speech at inappropriate lung volume levels and need to vary the depth of consecutive inhalations (Rosenbek, 1984; Yorkston et al., 1999)
- Terminate speech late in the expiratory cycle with resultant diminished loudness and vocal fry (Yorkston et al., 1999)
- Exhibit abnormal or maladaptive respiratory patterns, such as speaking on inhalation and forced expiration, often seen in patients with hyperkinetic dysarthria (Klasner, 1995) or patients with a concomitant cognitive impairment (Yorkston et al., 1999)

⁵The authors note, however, that this requires considerable coordination and precision of movement and may therefore be impractical for many children with cerebral palsy.

- Adopt a fatiguing pattern of breathing, such as excessive shoulder elevation (Yorkston et al., 1999)

Table 5 summarizes the strategies available for increasing the coordination and control of the respiratory/phonatory system, many of which entail the patient's awareness of the deficit and some form of auditory, visual or, occasionally, tactile feedback.

F. IMPROVING PHONATORY FUNCTION

Component F of the flowchart focuses on the management of speakers with phonatory dysfunction

from dysarthria. Reduced phonatory function often derives from incomplete or excessive adduction of the vocal folds. Hypoadduction of the vocal folds is most often associated with flaccid and hypokinetic dysarthrias, whereas hyperadduction of the vocal folds is more typical of people with spastic and hyperkinetic dysarthrias.

F1. Hypoadduction

A breathy voice may indicate air wastage and signal hypoadduction of the vocal folds. Speakers with unilateral or bilateral vocal fold weakness from muscle or nerve damage, or glottal incompetence (e.g., from bowed vocal folds), would typically man-

TABLE 5. Summary of techniques and corresponding levels of support for improving respiratory/phonatory coordination and control.

| Treatment Focus | Treatment Technique | Evidence-Based Support | Expert Opinion Only | No Support |
|------------------------|--|------------------------|---------------------|------------|
| Nonspeech Tasks | Biofeedback therapy to increase control of inhalation and exhalation | ✓ | | |
| | Practicing an effective breathing pattern (quick inspirations and slow, controlled exhalations) | | ✓ | |
| | Inspiratory checking without accompanying speech | | ✓ | |
| | Facilitating inspiratory coordination/speed through sniffing or exhalatory coordination through blowing | | ✓ | |
| | Practice switching between inspiration and expiration (see footnote 5) | | ✓ | |
| Speech Tasks | Biofeedback of chest wall movements and phonation | ✓ | | |
| | Improved awareness of the speech-breathing pattern | | ✓ | |
| | <i>Learning to evaluate and monitor</i> loudness level during speech | | ✓ | |
| | Combining pressing movements on the speaker's abdomen with instruction about getting to the "right size" during inhalation/exhalation for speech | | ✓ | |
| | Use of "optimal breath groups" | | ✓ | |
| | Inspiratory checking during speech | | ✓ | |
| | Training ability to vary depth of inhalation depending on length and volume of intended utterance | | ✓ | |

ifest hypoadduction. For speakers with hypoadductive behaviors, clinicians might consider physical strategies to enhance adduction (F2) or loudness training via the Lee Silverman Voice Treatment (F3).

F2. Physical Strategies To Enhance Adduction

There are various physical strategies that can be implemented to address phonatory impairment from vocal fold hypoadduction. These strategies fall under the broad categories of effort closure techniques, postural adjustments, and physical manipulations. As a whole, these treatment strategies are supported by expert opinion only. Evidence-based research does exist, however, for intervention using effort closure techniques for respiratory/phonatory dysfunction from dysarthria (de Angelis et al., 1997; Workinger & Netsell, 1992).

Effort closure techniques are exercises that increase the adductory forces of the vocal folds by modifying background of effort. First described by Froeschels in 1943, they are thought to maximize vocal fold adduction and may ultimately improve vocal fold strength (Duffy, 1995), resulting in increased loudness and reduced breathy/hoarse quality (Ramig, 1995). Examples of effort closure techniques include

- Clasping hands together and squeezing palms together as hard as possible (Aronson, 1990; Dworkin & Meleca, 1997; Yamaguchi et al., 1993)
- Interlacing hands and pulling outward (Yamaguchi et al., 1993)
- Pushing down on the speaker's raised arms in a rapid, uninterrupted motion (followed by the speaker doing the same motion unassisted) (de Angelis et al., 1997)
- Sitting in a chair, grasping the bottom with both hands, and pulling upward or pushing downward with both hands (Aronson, 1990; Dworkin & Meleca, 1997)
- Pushing against a lap board, the arms of a wheelchair, a grab bar, or against any other firm surface (Rosenbek, 1984)
- Pushing the head forward against resistance provided by the examiner's hands placed on the forehead of the speaker (Yamaguchi et al., 1993)
- Grunting and controlled coughing (to elicit phonatory behavior) (Duffy, 1995; Ramig et al., 1995).

A broad spectrum of speech stimuli can be used during implementation of these effort closure techniques. The nature of the stimuli will depend on the characteristics and abilities of the individual speaker and can range from sustained phonation to conversational discourse. Yamaguchi et al. (1993) note some limitations or drawbacks associated with effort closure techniques. Specifically,

1. laryngeal irritation occasionally occurs as a result of the excess effort,
2. extraneous compensatory movements may develop in some speakers, and
3. generalization to connected speech may not occur with the pushing technique alone and might require the use of additional carry-over exercises.

Solomon and Charron (1998) additionally noted that effort closure techniques should be used judiciously for speakers with spastic muscles from cerebral palsy. They recommended combining these techniques with relaxation and muscle-lengthening procedures.

Related to effort closure techniques is the *hard glottal attack*, that is, driving the vocal folds together with forceful, abrupt phonatory efforts. As discussed by Dworkin and Meleca (1997), this technique should be done with limitations to prevent the possibility of short-term abusive side effects and should only be incorporated with speakers who have failed to improve with other approaches. Speakers trained with this approach may benefit from tactile feedback (i.e., externally applied abdominal pressure; Dworkin & Meleca, 1997) or various forms of biofeedback from VisiPitch, a stethoscope (Dworkin & Meleca, 1997), or videoendoscopy (Ramig, 1995).

Postural adjustments also have been cited as a behavioral strategy for treating speakers with hypoadduction (Aronson, 1990; Duffy, 1995; Ramig, 1995; Yorkston et al., 1999). The primary strategy suggested for speakers with vocal fold weakness is to turn their head to the left or right during phonation. This postural change may increase the tension of the paretic/paralyzed fold (Ramig, 1995). However, head turning can be considered a pragmatically undesirable solution to the hypoadduction and may not lead to any true improvement in vocal fold adduction (Rosenbek & LaPointe, 1985). Duffy (1995) suggested that head turning should be considered compensatory and perhaps reserved for occasions when there is a situational demand for increased loudness.

Physical manipulations of the thyroid cartilage occasionally are used to improve vocal quality and loudness in speakers with hypoadduction. The external compression of the larynx is thought to achieve medialization of the vocal fold on the side of stimulation (Dworkin & Meleca, 1997; Ramig, 1995). This technique requires the speech-language pathologist to gently push on the larynx while the speaker phonates. It has been used to successfully elicit voicing from two speakers with whispered phonation following TBI (Sapir & Aronson, 1985). However, positive results from laryngeal compression in chronic conditions should prompt consideration of surgical treatment options, such as vocal fold repositioning or medialization (Dworkin & Meleca, 1997). As with head turns, digital manipulations of the thyroid cartilage may not effectively alter the true functioning of the vocal folds. Additionally, speakers often resist using this technique during conversation because of its unusual appearance (Yorkston et al., 1999). As such, it should perhaps be considered more as a compensation for situations that require a transitory increase in loudness (Duffy, 1995).

F3. Trigger Better Speech With Increased Loudness

Reduced speech loudness is one of the more common perceptual features of hypokinetic dysarthria associated with Parkinson disease. Achieving the goal of increasing loudness may also serve to trigger other speech benefits including improved articulation (Dromey, Ramig, & Johnson, 1995). One of the best-documented treatments for improving phonatory function is the Lee Silverman Voice Treatment (LSVT). LSVT is an intensive behavioral treatment program developed by Ramig and colleagues (Ramig et al., 1995) to improve the oral communication of speakers with hypokinetic dysarthria. The essential concepts of LSVT are

1. an exclusive focus on voice,
2. stimulation of high-effort productions with multiple repetitions,
3. intensive delivery of treatment,
4. enhancing sensory awareness of increased vocal loudness and effort, and
5. quantification of behavior.

Ramig and colleagues have conducted a series of studies to demonstrate the efficacy of LSVT, and they continue to investigate the use of LSVT in patients with idiopathic Parkinson disease and other neurologic disorders. A brief summary of the evolution of the research on LSVT can be found in the companion article (Yorkston, Spencer, & Duffy, this issue). The effectiveness of LSVT is well established in speakers with dysarthria from mild to moderate Parkinson disease. At present, there is less evidence to support the long-term efficacy of LSVT for speakers with severe Parkinson disease or other forms of basal ganglia disruption. Research on the use of LSVT with other neurologic disorders, such as multiple sclerosis, TBI, and stroke is promising, but it is premature to draw conclusions regarding efficacy in these clinical populations. Although positive outcomes in perceptual and acoustic measures have been documented, the physiological mechanism of change associated with improved speech production in these individuals has not been established (Fox, Morrison, Ramig, & Sapir, 2002).

F4. Hyperadduction

Hyperadduction of the vocal folds often occurs as the result of upper motor neuron system disorders, such as spastic dysarthria and spastic cerebral palsy, and hyperkinetic disorders of the basal ganglia control circuit, such as Huntington disease and adductor laryngeal dystonia (Ramig, 1995; Yorkston et al., 1999). Hyperadduction may also occur as a compensatory mechanism for managing weakness at the laryngeal or velopharyngeal level. These behaviors might be addressed with nonspeech techniques (F5) or certain speech tasks (F6).

F5. Nonspeech Techniques

Behavioral treatment of voice quality often is not undertaken for hyperadduction in speakers with dysarthria because it is quite difficult to modify and may result in a negligible improvement of intelligibility (Duffy, 1995). If the dysphonia is felt to contribute to the speaker's overall disability, traditional voice techniques designed to reduce laryngeal hyperadduction and increase airflow through the glottis may be appropriate (Pannbacker, 1998; Yorkston et al., 1999).⁶

⁶A separate module of the Practice Guidelines for dysarthria management will address medical interventions for voice/laryngeal impairments associated with the dysarthrias.

Nonspeech behavioral techniques for improving hyperadduction are generally comprised of relaxation strategies and biofeedback of airflow or the laryngeal muscles. Various forms of muscle *relaxation* have been noted in the literature, including

- Head, neck, and jaw musculature relaxation exercises, such as the “rag doll” and “chewing” techniques (Dworkin & Meleca, 1997)
- Gentle massage of the larynx and interconnecting strap musculature (Aronson, 1990; Dworkin & Meleca, 1997; Rosenbek & LaPointe, 1985)
- Progressive whole body relaxation (Jacobson, 1976; McClosky, 1977; Ramig, 1995).

The success of traditional relaxation procedures for improving hyperadduction from a dysarthria is inconsistent (Yorkston et al., 1999). To date, no studies demonstrating the efficacy of muscle relaxation or massage are available.

Several types of *biofeedback* may be used to address dysphonia from hyperadduction. Dworkin and Meleca (1997) suggested using VisiPitch to provide biofeedback of nonvocal airflow control. Speakers are asked to maintain a steady and controlled stream of air; therapeutic gains may translate into reduced glottal airflow resistance and enhanced respiratory support. Furthermore, to provide speakers with information on the level of laryngeal muscle tension, electromyographic and videoendoscopic feedback have been suggested (Ramig, 1995). There is no research available to support nonspeech biofeedback treatments for hyperadduction from a dysarthria.

F6. Speech Tasks

Speech tasks for addressing hyperadduction tend to focus on traditional tension-reducing strategies and biofeedback-enhanced relaxation. Traditional approaches to *reducing laryngeal tension* during speech include strategies for easy onset of phonation, such as the “yawn-sigh,” “chewing,” or “chanting” techniques (Darley, Aronson, & Brown, 1975; Dworkin & Meleca, 1997). As discussed by Ramig (1995), these approaches are based on the hypothesis that phonation produced in the context of “reflex-like” or “continuous phonation” responses will be more relaxed with less hyperadduction. The relaxed phonation can then be shaped into a relaxed vowel and through the hierarchy to conversational

speech. Murry and Woodson (1995) conducted effort-reducing voice therapy on a group of speakers with extrinsic muscle hyperfunction and airflow abnormalities following Botox injection for spasmodic dysphonia. The investigators found that speakers who received both Botox treatment and behavioral therapy demonstrated improved phonation in terms of increased airflow rate and acoustic measures.

Biofeedback during speech may help speakers monitor levels of extrinsic laryngeal muscle tension. This feedback can be electromyographic, videoendoscopic, or aerodynamic. Visual biofeedback of vocal fold vibrations would allow the speaker to practice modifying phonatory behaviors during vowel exercises. If airflow transducers are not available to provide aerodynamic biofeedback of transglottal airflow rate, Dworkin and Meleca (1997) suggested using the See Scape device (Pro-Ed). Speakers are instructed to practice easy voice initiation and control and to continuously strive for low levels of laryngeal muscle tension. A progressive hierarchy can be implemented from vowels, to syllables, words, sentences, and ultimately conversation.

For speakers with spasticity from cerebral palsy, it may help to move the speaker’s head from side to side or forward and backward while the speaker vocalizes quietly (McDonald, 1987, in Solomon & Charron, 1998). McDonald warns, however, that vocalization should be limited because the speaker is apt to develop tension and lose the ability to control the phonation as lung volume decreases. By extension, it has been suggested that a strained voice quality can be improved if pitch is increased, the head is rotated back, and the utterance is initiated at a high lung volume (Yorkston et al., 1999). These behaviors are associated with decreased airway resistance (Ramig, 1995).

No studies are available to document the effectiveness of biofeedback or postural adjustments in reducing hyperadduction from a dysarthria. Table 6 summarizes the treatment techniques and delineates the corresponding levels of support for methods targeting improved phonatory function.

G. MEASUREMENT OF OUTCOMES

Treatment outcomes can be measured in a variety of ways. The International Classification of Function (ICF) provides a scheme for organizing the consequences of conditions that can be chronic, such as dysarthria (International Classification of Function, Disability and Health, 2001). *Impair-*

TABLE 6. Summary of techniques and corresponding levels of support for improving phonatory function.

| Treatment Focus | Treatment Technique | Evidence-Based Support | Expert Opinion Only | No Support |
|---|---|------------------------|---------------------|------------|
| Hypoadduction | | | | |
| Physical strategies to enhance adduction | <i>Effort closure techniques</i> | ✓ | | |
| | Hard glottal attack | | ✓ | |
| | Postural adjustments (e.g., turning head to left or right) | | ✓ | |
| | Physical manipulations of thyroid cartilage | | ✓ | |
| Increased loudness | Lee Silverman Voice Treatment | ✓ | | |
| Hyperadduction | | | | |
| Nonspeech techniques | Muscle relaxation or massage | | ✓ | |
| | Biofeedback of nonvocal airflow | | ✓ | |
| Speech tasks | Tension-reducing strategies (e.g., easy onset of phonation techniques) | ✓ | | |
| | Biofeedback during speech to monitor extrinsic muscle tension | | ✓ | |
| | Postural adjustments (e.g., turning head from side to side) during vocalization | | ✓ | |

ments are problems in the physiological function of the body systems. In dysarthria, this would include measurable changes in the respiratory or phonatory subsystems. *Activity limitations* are reductions in the nature and extent of functioning at the level of the person: in dysarthria, the activity would be speaking. *Participation restrictions* reflect a person's limitations for involvement in a life situation. Applying the term to dysarthria, measures of participation reflect involvement in life situations that include speaking. The World Health Organization has recently combined the Activity and Participation levels of disablement (International Classification of Function, Disability and Health, 2001) to improve the accuracy of outcome classification. Examples from the extant literature of specific outcome measures are as follows:

1. Impairment level: vital capacity, sound pressure level, sustained phonation time, fundamental frequency, perceptual ratings of pitch
2. Activity/Participation level: speech intelligibility, speaking rate, self-evaluation of oral communication, depression inventories, probes outside of the clinic

As discussed in the companion article (Yorkston and colleagues, this issue), the vast majority of outcome measures in the research literature address the Impairment level to the exclusion of measures of Activity or Participation. This results in a biased and incomplete appraisal of treatment outcomes. To appropriately gauge the true success or failure of any given treatment, outcomes across levels of disablement should be measured.

H. CONSIDER AUGMENTATIVE AND ALTERNATIVE COMMUNICATION (AAC)

If a speaker remains unable to communicate satisfactorily following intervention, augmentative or alternative communication (AAC) modes should be pursued. The particular AAC systems chosen will depend on multiple factors, including the motor, sensory, cognitive, and linguistic abilities of the patient. A future module of the Practice Guidelines for Dysarthria Management will address speech supplementation issues. Refer to texts such as Beukelman and Mirenda (1998) for a more comprehensive overview of the management of people

with dysarthria using augmentative and alternative forms of communication. Some AAC devices specific to respiratory/phonatory dysfunction are outlined by Duffy (1995) and include

- Vocal intensity controllers
- Portable amplification systems
- Electrolarynges (artificial larynx).

A *vocal intensity controller* informs the speaker when their loudness has fallen below a certain criterion level. It is most appropriate for patients with adequate speaking rate and articulation. Rubow and Swift (1985) used a portable biofeedback device for a patient with breathiness, reduced loudness, and mild articulatory imprecision from Parkinson disease. The patient demonstrated improvement perceptually and acoustically, both within and outside of treatment sessions.

Portable amplification systems can be used for patients with decreased loudness but adequate articulation. Simpson et al. (1988) demonstrated success with a voice amplifier for a patient with severe dysarthria from basilar artery infarct. The amplifier was employed following negligible improvement from respiratory prosthetic and biofeedback treatments. Cariski and Rosenbek (1999) investigated the effect of an amplification system on two patients with articulatory imprecision. The authors reported that the Speech Enhancer (Electronic Speech Enhancement, Inc.) was designed to both amplify and clarify dysarthric speech. Treatment with the Speech Enhancer, coupled with behavioral therapy to increase phonatory effort, substantially improved intelligibility in two patients with severe hypokinetic dysarthria. Both patients had failed with traditional voice amplification and behavioral therapy. An *electrolarynx* may be an option for patients who are aphonic or severely breathy, but have good articulation skills. No studies examining the effectiveness of this method have been conducted.

CONCLUSIONS

Decisions regarding the behavioral management of respiratory/phonatory dysfunction are not made in a vacuum. There are innumerable influential factors, including concomitant involvement of other speech subsystems, that interact to render clinical decision making a complex, demanding process. Guidance for management decisions can be provided, in part, from knowledge of the support available for various treatment options. Evidence-based support exists for at least two approaches in each of

the following three main treatment paths: (a) improving respiratory support, (b) increasing respiratory/phonatory coordination and control, and (c) improving phonatory function. The most studied treatment approach is the LSVT, which has demonstrated treatment efficacy for people with mild-moderate dysarthria from idiopathic Parkinson disease. If candidacy requirements for an evidence-based technique are met, clinicians may be directed to that particular treatment for an individual patient. Furthermore, expert opinion is available for many management options. Although these techniques do not have the desired support of the research literature, they serve to offer therapeutic guidance to clinicians with the caveat that supportive evidence is lacking. Finally, it is hoped that the delineation of management strategies and the corresponding levels of support will prompt treatment efficacy research in the areas particularly in need of attention, such as the examination of postural adjustments and speech tasks for improving respiratory support, speech tasks for increasing respiratory/phonatory coordination, and nonspeech techniques for decreasing hyperadduction.

Acknowledgment This work was supported in part by the Academy of Neurologic Communication Disorders and Sciences (ANCDS), ASHA (SID 2 and VP for Clinical Practice in SLP), Department of Veterans Affairs, and a personnel training grant (T32DC00033) from the National Institute on Deafness and Other Communication Disorders, National Institutes of Health, to the University of Washington. The authors wish to acknowledge other members of the Writing Committee for Practice Guidelines in Dysarthria, including David R. Beukelman, Lee Ann Golper, Robert M. Miller, Edythe A. Strand, and Marsha Sullivan. We also wish to acknowledge the panel of experts who provided careful review of the Technical Report upon which this article was based.

Address correspondence to Kristie A. Spencer, Ph.C., Department of Speech and Hearing Sciences, University of Washington, 1417 NE 42nd Street, Seattle, WA 98105 USA.
e-mail: kas@u.washington.edu

REFERENCES

- Adams, S. G., & Page, A. D. (2000). Effects of selected practice and feedback variables on speech motor learning. *Journal of Medical Speech-Language Pathology*, 8(4), 215-220.

- Aronson, A. E. (1990). *Clinical voice disorders* (3rd ed.). New York: Thieme.
- Beckett, R. L. (1971). The respirometer as a diagnostic and clinical tool in the speech clinic. *Journal of Speech and Hearing Disorders*, 36(2), 235–241.
- Beukelman, D. R., & Mirenda, P. (1998). *Augmentative and alternative communication: Management of severe communication disorders in children and adults* (2nd ed.). Baltimore: Paul H. Brookes.
- Blumberg, M. (1955). Respiration and speech in the cerebral palsied child. *American Journal of Disabled Children*, 89, 48–53.
- Brookshire, R. (1992). *An introduction to neurogenic communication disorders* (4th ed.). St. Louis, MO: Mosby-Year Book.
- Cariski, D., & Rosenbek, J. (1999). Clinical note: The effectiveness of the Speech Enhancer. *Journal of Medical Speech-Language Pathology*, 7(4), 315–322.
- Cerny, F. J., Panzarella, K. J., & Stathopoulos, E. (1997). Expiratory muscle conditioning in hypotonic children with low vocal intensity levels. *Journal of Medical Speech-Language Pathology*, 5, 141–152.
- Chenery, H. J. (1998). Perceptual analysis of dysarthric speech. In B. E. Murdoch (Ed.), *Dysarthria: A physiological approach to assessment and treatment* (pp. 36–67). Cheltenham, UK: Stanley Thornes.
- Coelho, C. A., Gracco, V. L., Fourakis, M., Rossetti, M., & Oshima, K. (1994). Application of instrumental techniques in the assessment of dysarthria: A case study. In J. A. Till, K. M. Yorkston, D. R. Beukelman (Eds.), *Motor speech disorders: Advances in assessment and treatment* (pp. 113–118). Baltimore: Paul H. Brookes.
- Daniel-Whitney, B. (1989). Severe spastic-ataxic dysarthria in a child with traumatic brain injury: Questions for management. In K. M. Yorkston & D. R. Beukelman (Eds.), *Recent advances in clinical dysarthria* (pp. 129–137). Austin, TX: Pro-Ed.
- Darley, F. L., Aronson, A. E., & Brown, J. R. (1975). *Motor speech disorders*. Philadelphia: W. B. Saunders.
- de Angelis, E. C., Mourao, L. F., Ferraz, H. B., Behlau, M. S., Pontes, P. A., & Andrade, L. A. (1997). Effect of voice rehabilitation on oral communication of Parkinson's disease patients. *Acta Neurologica Scandinavica*, 96(4), 199–205.
- Dromey, C., Ramig, L. O., & Johnson, A. B. (1995). Phonatory and articulatory changes associated with increased vocal intensity in Parkinson disease: A case study. *Journal of Speech & Hearing Research*, 38(4), 751–764.
- Duffy, J. R. (1995). *Motor speech disorders: Substrates, differential diagnosis, and management*. St. Louis, MO: Mosby.
- Dworkin, J., & Meleca, R. (1997). *Vocal pathologies: Diagnosis, treatment and case studies*. San Diego, CA: Singular Publishing Group.
- Ferrand, C. T. (1995). Effects of practice with and without knowledge of results on jitter and shimmer levels in normally speaking women. *Journal of Voice*, 9(4), 419–423.
- Froeschels, E. (1943). A contribution to the pathology and therapy of dysarthria due to certain cerebral lesions. *Journal of Speech Disorders*, 8, 301–321.
- Fox, C. M., Morrison, C. E., Ramig, L. O., & Sapir, S. (2002). Current perspectives on the Lee Silverman Voice Treatment (LSVT) for individuals with idiopathic Parkinson disease. *American Journal of Speech-Language Pathology*, 11(2), 111–123.
- Gerratt, B. R., Till, J. A., Rosenbek, J. C., Wertz, R. T., & Boysen, A. E. (1991). Use and perceived value of perceptual and instrumental measures in dysarthria management. In C. A. Moore, K. M. Yorkston, & D. R. Beukelman (Eds.), *Dysarthria and apraxia of speech: Perspectives on management* (pp. 77–93). Baltimore: Paul H. Brookes.
- Hammen, V. L., & Yorkston, K. M. (1994). Respiratory patterning and variability in dysarthric speech. *Journal of Medical Speech-Language Pathology*, 2(4), 253–262.
- Hardy, J. (1964). Lung function of athetoid and spastic quadriplegic children. *Developmental and Child Neurology*, 6, 378–388.
- Hayden, D. A., & Square, P. A. (1994). Motor speech treatment hierarchy: A systems approach. *Clinics in Communication Disorders*, 4(3), 162–174.
- Hixon, T. (1987). *Respiratory function in speech and song*. Boston: College-Hill Press.
- Hixon, T. (1993). *Clinical evaluation of speech breathing disorders: Principles and methods, Telerounds #7*. Tucson: National Center for Neurogenic Communication Disorders: University of Arizona.
- Hixon, T., Hawley, J., & Wilson, J. (1982). An around-the-house device for the clinical determination of respiratory driving pressure. *Journal of Speech & Hearing Disorder*, 47, 413–415.
- Hixon, T., & Hoit, J. (2000). Physical examination of rib cage wall by the speech-language pathologist. *American Journal of Speech-Language Pathology*, 9, 179–196.
- Hixon, T. J., & Hoit, J. D. (1998). Physical examination of the diaphragm by the speech-language pathologist. *American Journal of Speech-Language Pathology*, 7(4), 37–45.
- Hixon, T. J., & Hoit, J. D. (1999). Physical examination of the abdominal wall by the speech-language pathologist. *American Journal of Speech-Language Pathology*, 8(4), 335–346.
- Hixon, T., Putnam, A., & Sharpe, J. (1983). Speech production with flaccid paralysis of the rib cage, diaphragm, and abdomen. *Journal of Speech & Hearing Disorders*, 48, 315–327.
- Hoberman, S. E., & Hoberman, M. (1960). Speech habilitation in cerebral palsy. *Journal of Speech and Hearing Disorders*, 25(2), 111–123.
- Hoit, J. (1995). Influence of body position on breathing and its implication for the evaluation and treatment of speech and voice disorders. *Journal of Voice*, 9, 341–347.
- Horton, S. K., Murdoch, B. E., Theodoros, D. G., & Thompson, E. C. (1997). Motor speech impairment in

- a case of childhood basilar artery stroke: Treatment directions derived from physiological and perceptual assessment. *Pediatric Rehabilitation*, 1(3), 163–177.
- International Classification of Function, Disability and Health*. (2001). World Health Organization. Retrieved Dec 10, 2001, from the World Wide Web: <http://www3.who.int/icf/icftemplate.cfm>
- Jacobson, E. (1976). *You must relax* (5th ed.). New York: McGraw Hill.
- Jones, E. I., Hardy, J. C., & Shipton, H. W. (1963). Development of electrical stimulation in modifying respiratory patterns of children with cerebral palsy. *Journal of Speech and Hearing Disorders*, 28(3), 230–238.
- Kent, R. D. (1997). The perceptual sensorimotor examination of motor speech disorders. In M. R. McNeil (Ed.), *Clinical management of sensorimotor speech disorders* (pp. 27–48). New York: Thieme Medical Publishers.
- Kent, R. D., Kent, J. F., Duffy, J., & Weismer, G. (1998). The dysarthrias: Speech-voice profiles, related dysfunctions, and neuropathology. *Journal of Medical Speech-Language Pathology*, 6(4), 165–211.
- Klasner, E. R. (1995). Speech treatment for individuals with Huntington's disease. *Special Interest Divisions: Neurophysiology and Neurogenic Speech and Language Disorders*, 5(3), 12–15.
- Linebaugh, C. (1983). Treatment of flaccid dysarthria. In W. H. Perkins (Ed.), *Dysarthria and apraxia* (pp. 59–67). New York: Thieme-Stratton.
- McClosky, D. G. (1977). General techniques and specific procedures for certain voice problems. In M. Cooper & M. H. Cooper (Eds.), *Approaches to vocal rehabilitation* (pp. 138–152). Springfield, IL: Charles C Thomas.
- McDonald, E. T. (1987). Speech production problems. In E. T. McDonald (Ed.), *Treating cerebral palsy* (pp. 171–190). Austin, TX: Pro-Ed.
- McHenry, M. A., & Minton, J.T. (1998). Speech-breathing analysis procedures for speakers who are difficult to assess. In M. P. Cannito, K. M. Yorkston, & D. R. Beukelman (Eds.), *Neuromotor speech disorders: Nature, assessment and management* (pp. 167–180). Baltimore: Paul H. Brookes.
- McNamara, R. D. (1983). A conceptual holistic approach to dysarthria treatment. In W. Berry (Ed.), *Clinical Dysarthria* (192–202). Austin, TX: Pro-Ed.
- Murdoch, B. E., Pitt, G., Theodoros, D. G., & Ward, E. C. (1999). Real-time continuous visual biofeedback in the treatment of speech breathing disorders following childhood traumatic brain injury: Report of one case. *Pediatric Rehabilitation*, 3(1), 5–20.
- Murry, T., & Woodson, G. (1995). Combined-modality treatment of adductor spasmodic dysphonia with Botulinum toxin and voice therapy. *Journal of Voice*, 9, 460–465.
- Netsell, R. (1992). Speech production following traumatic brain injury: Clinical and research implications. *Special Interest Divisions: Neurophysiology and Neurogenic Speech and Language Disorders*, 2, 1–8.
- Netsell, R. W. (1995). Speech rehabilitation for individuals with unintelligible speech and dysarthria: The respiratory and velopharyngeal systems. *Special Interest Divisions: Neurophysiology and Neurogenic Speech Language Disorders*, 5(4), 6–9.
- Netsell, R. W. (1998). Speech rehabilitation for individuals with unintelligible speech and dysarthria: The respiratory and velopharyngeal systems. *Journal of Medical Speech-Language Pathology*, 6(2), 107–110.
- Netsell, R., & Daniel, B. (1979). Dysarthria in adults: Physiologic approach to rehabilitation. *Archives of Physical Medicine and Rehabilitation*, 60, 502–508.
- Netsell, R., & Hixon, T. (1978). A noninvasive method for clinically estimating subglottal air pressure. *Journal of Speech and Hearing Disorders*, 43, 326–330.
- Netsell, R., & Rosenbek, J. C. (1985). *Treating the dysarthrias. Speech and language evaluation in neurology: Adult disorders*. New York: Grune & Stratton.
- Pannbacker, M. (1998). Voice treatment techniques: A review and recommendations for outcome studies. *American Journal of Speech-Language Pathology*, 7(3), 49–64.
- Ramig, L. (1995). Voice therapy for neurologic disease. *Otolaryngology and Head and Neck Surgery*, 3, 174–182.
- Ramig, L. A. (1986). Acoustic analyses of phonation in patients with Huntington's disease. *Annals of Otolaryngology Rhinology & Laryngology*, 95, 288–293.
- Ramig, L. O. (1992). The role of phonation in speech intelligibility: A review and preliminary data from patients with Parkinson's Disease. In R. D. Kent (Ed.), *Intelligibility in speech disorders: Theory, measurement and management* (pp. 119–156). Amsterdam: John Benjamins.
- Ramig, L. O., Countryman, S., Fox, C., & Sapir, S. (2002). Speech, voice, and swallowing disorders. In S. Factor & W. Weiner (Eds.), *Parkinson's disease: Diagnosis and clinical management* (pp. 75–86). New York: Demos Medical Publishing.
- Ramig, L. O., & Dromey, C. (1996). Aerodynamic mechanisms underlying treatment-related changes in vocal intensity in patients with Parkinson disease. *Journal of Speech & Hearing Research*, 39(4), 798–807.
- Ramig, L. O., Pawlas, A. A., & Countryman, S. (1995). *The Lee Silverman Voice Treatment*. Iowa City, IA: National Center for Voice and Speech.
- Redstone, F. (1991). Respiratory components of communication. In M. B. Langley & L. J. Lombardino (Eds.), *Neurodevelopmental strategies for managing communication disorders in children with severe motor dysfunction* (pp. 29–48). Austin, TX: Pro-Ed.
- Robin, D. A., Solomon, N. P., Moon, J. B., & Folkins, J. W. (1997). Nonspeech assessment of speech production mechanism. In M. R. McNeil (Ed.), *Clinical management of sensorimotor speech disorders* (pp. 49–62). New York: Thieme Medical Publishers.

- Rosenbek, J. (1984). Treating the dysarthric talker. *Seminars in Speech and Language, 5*, 359–384.
- Rosenbek, J. C., & LaPointe, L. L. (1985). The dysarthrias: Description, diagnosis, and treatment. In D. Johns (Ed.), *Clinical management of neurogenic communication disorders* (pp. 97–152). Boston: Little, Brown.
- Rubow, R., & Swift, E. (1985). A microcomputer-based wearable biofeedback device to improve transfer of treatment in parkinsonian dysarthria. *Journal of Speech and Hearing Disorders, 50*, 178–185.
- Sapir, S., & Aronson, A. E. (1985). Aphonia after closed head injury: Aetiologic considerations. *British Journal of Disorders of Communication, 20*, 289–296.
- Schmidt, R. A., & Lee, T. D. (1999). *Motor control and learning: A behavioral emphasis* (3rd ed.). Champaign, IL: Human Kinetics.
- Schulz, G. M., Sulc, S., Leon, S., & Gilligan, G. (2000). Speech motor learning in Parkinson's disease: Preliminary data. *Journal of Medical Speech-Language Pathology, 8*(4), 243–248.
- Simpson, M. B., Till, J. A., & Goff, A. M. (1988). Long-term treatment of severe dysarthria: A case study. *Journal of Speech & Hearing Disorders, 53*, 433–440.
- Smeltzer, S. C., Skurnick, J. H., Troiano, R., Cook, S. D., Duran, W., & Lavietes, M. H. (1992). Respiratory function in multiple sclerosis: Utility of clinical assessment of respiratory muscle function. *Chest, 101*(2), 479–484.
- Solomon, N. P., & Charron, S. (1998). Speech breathing in able-bodied children and children with cerebral palsy: A review of the literature and implications for clinical intervention. *American Journal of Speech-Language Pathology, 7*, 61–78.
- Solomon, N. P., Garlitz, S. J., & Milbrath, R. L. (2000). Respiratory and laryngeal contributions to maximum phonation duration. *Journal of Voice, 14*(3), 331–340.
- Spencer, K. A., Yorkston, K. M., Duffy, J. R., and colleagues. (2002). Practice guidelines for dysarthria: Evidence for the behavioral management of the respiratory/phonatory system (Technical Report 3). (<http://www.ncds.duq.edu/guidelines.html>) Minneapolis, MN: Academy of Neurologic Communication Sciences and Disorders.
- Steinhauer, K., & Grayhack, J. P. (2000). The role of knowledge of results in performance and learning of a voice motor task. *Journal of Voice, 14*(2), 137–145.
- Thompson, E. C., Murdoch, B. E., & Theodoros, D. G. (1997). Variability in upper motor neurone-type dysarthria: An examination of five cases with dysarthria following cerebrovascular accident. *European Journal of Disorders of Communication, 32*(4), 397–427.
- Thompson-Ward, E. C., & Murdoch, B. E. (1998). Instrumental assessment of the speech mechanism. In B. E. Murdoch (Ed.), *Dysarthria: A physiological approach to assessment and treatment* (pp. 68–101). Cheltenham, UK: Stanley Thornes.
- Thompson-Ward, E. C., Murdoch, B. E., & Stokes, P. D. (1997). Biofeedback rehabilitation of speech breathing for an individual with dysarthria. *Journal of Medical Speech-Language Pathology, 5*(4), 277–290.
- Verdolini, K. (1994). Voice disorders. In J. B. Tomblin, H. L. Morris, & D. C. Spriestersbach (Eds.), *Diagnosis in speech-language pathology* (pp. 247–330). San Diego, CA: Singular Publishing Group.
- Volin, R. A. (1998). A relationship between stimulability and the efficacy of visual biofeedback in the training of a respiratory control task. *American Journal of Speech-Language Pathology, 7*(1), 81–90.
- Warren, D. (1996). Regulation of speech aerodynamics. In N. Lass (Ed.), *Principles of experimental phonetics* (pp. 46–92). St. Louis, MO: Mosby.
- Watson, P. J., & Hixon, T. J. (2001). Effects of abdominal trussing on breathing and speech in men with cervical spinal cord injury. *Journal of Speech, Language, and Hearing Research, 44*(4), 751–762.
- Weismer, G. (1985). Speech breathing: Contemporary views and findings. In R. Daniloff (Ed.), *Speech science* (pp. 47–71). Austin, TX: Pro-Ed.
- Workinger, M. S., & Netsell, R. (1992). Restoration of intelligible speech 13 years post-head injury. *Brain Injury, 6*(2), 183–187.
- Yamaguchi, H., Yotsukura, T., Sata, H., Watanabe, Y., Hirose, H., Kobayashi, N., & Bless, D. M. (1993). Pushing exercise program to correct glottal incompetence. *Journal of Voice, 7*(1), 3.
- Yorkston, K. M., Beukelman, D. R., & Bell, K. R. (1988). *Clinical management of dysarthric speakers*. Austin, TX: Pro-Ed.
- Yorkston, K. M., Beukelman, D. R., Strand, E. A., & Bell, K. R. (1999). *Management of motor speech disorders in children and adults*. Austin, TX: Pro-Ed.
- Yorkston, K. M., Strand, E. A., & Miller, R. M. (1996). Progression of respiratory symptoms in amyotrophic lateral sclerosis: Implications for speech function. In D. A. Robin, K. M. Yorkston, & D. R. Beukelman (Eds.), *Disorders of motor speech: Assessment, treatment and clinical characterization* (pp. 193–204). Baltimore: Paul H. Brookes.