Objective: To investigate the dynamics of speech shunt muscle in patients with Pearson near-total laryngectomy by needle electromyography and correlation of ability to activate shunt muscle with speech production.

Design and Settings: Prospective study of patients with near-total laryngectomy at 2 hospital-based academic tertiary care centers.

Participants and Intervention: Fourteen patients with near-total laryngectomy were subjected to percutaneous needle electromyographic study of the shunt muscle.

Main Outcome Measures: Speech ability, electromyographic evidence of viable muscle in shunt wall, and ability to activate shunt muscle were recorded.

Results: Twelve of 14 patients had good speech; 11 had evidence of viable shunt muscle; and 9 were able to activate muscle by phonation, swallowing, or deep breathing, indicating preserved innervation. Six of the 12 patients with speech ability and 1 of the 2 patients without speech ability were able to recruit motor units during attempted phonation.

Conclusions: Electromyography demonstrated viable muscle with retained innervation in 64% of the patients with near-total laryngectomy, proving its “dynamic” nature. However, the usefulness of shunt muscle activation in speech and prevention of aspiration needs further confirmation.
PATIENTS AND METHODS

Fourteen subjects (mean age, 55.8 years; male-female ratio, 13:1) who had undergone NTL 2 months to 4 years earlier for carcinoma of the larynx and piriform sinus were included in the study after informed consent was obtained. Near-total laryngectomy was performed by the method described by Pearson et al. All subjects received training by a speech pathologist to develop “shunt speech.” Ten of these subjects were described in an earlier NTL study.

Electromyography of the shunt muscle was performed using a conventional concentric needle on a 4-channel EMG system (Dantec Counterpoint MK2, Dantec Electronik, Skovland, Denmark) with a bandwidth of 2 Hz to 10 kHz. Electromyography is a simple method of studying potential changes in muscle at rest and during contraction using a concentric needle electrode. The potentials recorded from a few muscle fibers at the needle tip are displayed on an oscilloscope screen. A healthy muscle is silent at rest. On contracting, groups of muscle fibers innervated by individual nerve fibers are activated, the action potentials of which—called motor unit potentials (MUPs)—are seen as triphasic waves. The MUPs from healthy laryngeal muscles are 0.1 to 0.4 mV in amplitude and 3 to 6 milliseconds in duration.5 Injury to, or denervation of, muscle results in spontaneous muscle activity at rest seen on the screen as small potentials called fibrillation and positive sharp waves (Figure 1); activity elicited by needle insertion or movement, called insertional activity, is also increased. Loss of innervation also results in a decrease in the number of MUPs recruited and an appearance of polyphasic MUPs (with more than 4 phases) owing to reinervation by intact nerve fibers.

The needle was inserted percutaneously above the tracheostomy stoma in the midline of neck to a depth of 1.0 to 2.5 cm under EMG guidance, targeting the tracheopharyngeal shunt muscle. Positioning of the needle tip in the muscle was recognized by a burst of insertional activity or appearance of other muscle electrical activity. Care was taken not to insert the needle so deeply that the shunt lumen was reached. Duration of the insertional activity and spontaneous activity were first studied. The patient was then asked to breathe deeply, to phonate (attempt to make a high-pitched sound, such as eee) with the stoma occluded with a thumb, and to swallow in sequence. Any recruitable MUPs during these procedures were studied. An attempt was made to correlate the ability of shunt speech with EMG findings. Fisher exact probability test was used for statistical correlation.

RESULTS

Of the 14 patients studied, 12 had good shunt speech and 2 had no speech ability. None had aspiration significant enough to produce symptoms. The EMG findings are summarized in the Table. Three subjects (2 speakers [patients 2 and 6] and 1 nonspeaker [patient 5]) had no EMG activity at rest or with any form of effort, suggesting either absence of any viable muscle in the shunt wall or its inaccessibility to the needle. All the remaining 11 subjects (10 speakers and 1 nonspeaker) had increased insertional activity or spontaneous activity in the form of fibrillations or positive sharp waves, indicating denervation. The subjects (6/12) with good speech did not show MUPs on attempted phonation. Four of them (Nos. 2, 6, 8, and 14) did not show MUPs at rest, on deglutition, or on deep breathing either. A “geographic miss” probably accounts for this finding. In patients 11 and 13, there were recordable MUPs on deglutition, on deep breathing, or at rest; this indicates that significant coordinated muscle activity probably does not occur during phonation. Phonation and swallowing elicited MUPs in 7 subjects, while deep breathing elicited MUPs in 6 subjects (Figure 1 and Figure 2). None of these procedures elicited a complete recruitment pattern with MUPs abundant enough to obliterate the baseline; all had few or sometimes only 1 MUP firing at rapid rates of more than 15 Hz, suggesting incomplete recruitment and motor unit dropout. At least 1 of the 3 acts was able to elicit MUPs in 9 of the 14 subjects, indicating the presence of intact innervation of some muscle fibers.

No statistical correlation was observed between the ability to speak and the ability to activate MUPs specifically by phonation or by any of the 3 modes of activation (P>.05). Of the 12 patients who could speak, only...
half could activate MUPs during speech; the rest had no MUPs activated by phonation despite preserved speech. One of the 2 patients who had no speech ability was able to activate MUPs by attempted phonation.

**COMMENT**

To the best of our knowledge, this is the first attempt at an EMG study of the dynamics of the tracheopharyngeal shunt. We observed evidence of viable muscle with intact innervation in the shunt wall in 9 (64.3%) of 14 subjects, thus proving the dynamic nature of the shunt. However, all these muscles also showed evidence of denervation and the presence of only a few recruitable MUPs. These findings suggest a significant loss of, or injury to, axons and/or muscle, possibly during surgery. The remaining 5 subjects probably had muscle that was completely denervated or atrophied and fibrosed. More importantly, almost all the subjects (other than patients 2, 5, and 6, who did not show any recordable MUPs, probably because of an electrode implantation into a nonrepresentative area) showed recordable MUPs at rest. This would seem to imply that the tonicity imparted by residual viable muscles keeps the “mouth” of the tracheopharyngeal shunt closed at all times unless it is forced apart by an upward blast of expired air from the lungs, which leads to speech production. Protection of the tracheobronchial complex is a function that is older than speech in the evolutionary scale, and the tracheopharyngeal speech shunt probably resembles one of the primitive sphincters recreated by the surgeon to avert troublesome aspiration. Our findings seem to suggest that if any function is deemed to be dynamic it is probably this sphincteral mechanism.

Our observations suggest that muscle with intact innervation in the shunt is probably not essential for good shunt speech: 6 of the 12 subjects with good speech ability had no activable MUPs by phonation. Furthermore, 1 of the 2 subjects who could not speak was able to activate MUPs during attempted phonation. Although the number of patients we studied is small, there was no correlation between ability of shunt speech and the ability to recruit motor units in the shunt muscle by phonation, swallowing, or deep breathing. The availability of tracheopharyngeal air conduit for the normal articulation, together with the bellows function of the respiratory muscles, possibly accounts for the better quality of speech in these patients. Similarly, activation of the shunt muscles during deglutition may not be adequate evidence of their efficacy in preventing aspiration. However, the tone imparted by the residual muscle keeps the mouth of the shunt closed at all times except during pho-
nation, an observation that has often been documented by videoendoscopy at our center and others. The strategic location of the mouth beneath the tongue base further enhances the “waterfall effect,” i.e., food bolus propulsion directed above and over the closed mouth of the shunt by the anteroposteriorly progressing lingual peristalsis. The physiology of swallowing is currently being studied and is under evaluation by videofluoroscopy at our center.

One study that addresses the issue of shunt dynamics in NTL used electrolaryngography, wherein changes in impedance to flow of an electric current applied through surface electrodes across the larynx were used to test the mobility of vocal cords. Impedance decreased greatly when the vocal cords were apposed to one another, while it increased when they were separated. Among the 8 subjects with NTL who could speak with digital stomal occlusion, the electrolaryngographic pattern was found to be similar to that in normal subjects. The author concluded that variation in impedance pattern was a result of the dynamic nature of the shunt. While electrolaryngography provides evidence of mobility of the shunt wall during phonation, it does not provide evidence of actual contraction of the muscles. Mechanical separation of the shunt wall by air being forced through the shunt may not be differentiated from movement due to muscle contraction. Other methods of studying the influence of the shunt muscle on the air column (e.g., aerodynamic studies), as well as activation of the muscle during phonation, are appropriate to explore these issues.

The human larynx is an organ of sophisticated function. The various muscles in this small organ are activated in a highly synchronized fashion during phonation and deglutition. These muscles probably continue to be activated by the brain in the same sequences, even when they are displaced, as long as innervation is intact. However, during surgery, realignment of the actual muscles used in fashioning the shunt is arbitrary and precludes any statement as to whether these, if functional, would enable better shunt speech or prevent aspiration. The muscles used are collectively wrapped around the mucosa; it is difficult to visualize such a structure showing coordinated contractions and relaxation synchronous with the complex acts of swallowing and phonation. If further studies prove the efficacy of the shunt muscle in enhancing speech or preventing aspiration in NTL, it may be worth an effort by the surgeon to improve methods of muscle realignment and to prevent denervation of residual muscles used in the shunt.

**CONCLUSIONS**

We studied functioning of the shunt muscle with EMG in 14 patients with NTL. While the results indicate that the shunt is indeed dynamic in most of these patients, the need for coordinated muscle action in enabling good speech and prevention of aspiration remains to be proved.

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