Electrotherapy and the Human Voice: A Literature Review of the Historical Origins and Contemporary Applications

*Marina Gilman and †Sander L. Gilman

Atlanta, Georgia

Summary: The present article surveys the literature on the electrotherapy treatment for voice disorders from the mid-18th century to World War I (1914–1918) and the post 1970s reappearance of such therapies. The reappearance of electrotherapy as treatment for voice disorders in the past 20 years has been heralded as a major breakthrough. In light of our reading of the scientific literature of the 19th century, it can be shown to repeat many of the presuppositions of electrotherapists of that time. The current resurgence of interest and research in electrical stimulation of the larynx is buoyed by technological innovations analogous to those in the 19th century. Although the current state of research has enhanced our understanding of vocal fold physiology, it does not necessarily provide a new therapeutic approach as a survey of the most recent literature shows.

Key Words: Electrotherapy—Electrical stimulation—Voice disorders—Dysphagia—Vocal fold paralysis—Voice therapy—History.

The recent (re)appearance of electrotherapy for voice and swallowing disorders recalls how important such therapies were for the treatment of analogous problems for over 150 years, and how precipitously such procedures were abandoned.

The ''age of electricity'' saw the application of this ''new'' medium to medical therapy, as a late 19th-century advocate noted.[1] There were, in fact, at least two ''ages'' of electrotherapy—each age dependent on the meaning associated with electricity as a cutting-edge technology. As with virtually every technological innovation since the discovery of fire and the invention of the wheel, electricity was immediately applied to the treatment of pathologies, including those of the voice. Yet in each age of its development, different meanings were attached to the function of ''electricity'' and certainly to the question of what it meant to provide succor to that most amorphous of human functions, the voice. This tale provides a double insight into how voice therapy was constituted in the light of technological innovation and the implications of the historical record for the present (nascent) fascination with electrical stimulation of the larynx.

Accepted for publication August 24, 2006.

Presented at the Voice Foundation 35th Annual symposium: Care of the Professional Voice May 31–June 4, 2006, The Westin Philadelphia Hotel, Philadelphia, PA.

From *The Emory Voice Center, Department of Otolaryngology, Emory University, Atlanta, Georgia; and the †Graduate Institute of Liberal Arts, Emory University, Atlanta, Georgia.

Address correspondence and reprint requests to Marina Gilman, 2651 Briarlake Road NE, Atlanta, Georgia 30345. E-mail: Mgilman787@aol.com

Journal of Voice, Vol. 22, No. 2, pp. 219–231

0892-1997/$34.00

doi:10.1016/j.jvoice.2006.08.016

The 18th century was, in a complex way, the first and most extraordinary of the ages of electricity. It saw the development of the electrostatic generator by Otto von Guericke in 1660, and the harnessing of electrical energy with the development of the Leyden Jar by Pieter van Musschenbroek in 1746. The possibility to store and use electricity on demand led to its regular usage in therapy. It was of relative low voltage, wattage, and amperage: it was, however, often unreliable in its intensity and the therapists who used electricity warned about its risk. Although static electricity was used in a limited way, it was only in the middle of the 18th century that the powerful association of electricity as a new technology with new therapies such as magnetism and mesmerism (detested by Benjamin Franklin) led to a wide range of therapeutic applications[2] (Table 1).

Given the close association of therapy with religion (this is the age of radical secularization), the most impressive therapeutic applications of all of the new therapies were to the treatment of precisely those pathologies (blindness, madness, deafness, and lameness) that haunt the Biblical narratives of cure.[3] Treatments of the voice play a minor role: nevertheless the voice was the consistent object of concern from the 18th century through the early 20th century. When we look at the ''standard'' texts on the topic, those that were popular or were cited as authorities, when we look at the handbooks or the textbooks, a pattern begins to emerge. In the first generation of therapy with electricity, the question was what aspects of the voice were appropriate and how was such therapy understood.

John Wesley, the founder of Methodism and the author of one of the best-selling medical handbooks in England from 1750–1850, noted in 1747 that ''electrifying in a proper manner cures'' a wide range of illnesses from ''blindness to wens,'' [a skin cyst].[4] This claim leads to his 1759 book of electrical treatments in which he builds on the theoretical work of Benjamin Franklin and the speculative, medical applications of Richard Lovett.[5] Wesley claims the widest efficacy for the application of static electricity. Among the treatments mentioned is that of the ''sore throat.''[4] He provides a case study of a woman ''taking cold, [who] was seized with a sore throat, which grew worse and worse for six days. She then could not swallow even a bit of bread soaked in tea. The same morning she was electrified, so as to direct the shock in a right line thro' the part affected. By the time she got home she could eat anything. Two shocks more made a perfect cure.''[4] One further case study, that of a ''palsy that affected speech was taken from Richard Lovett[4]: ''April 18th 1759. A remarkable case happened at Edinburgh. Robert Moubray, in the beginning of January was struck with a palsy of the tongue, and soon after entirely lost the use of his speech. Last week he began being electrified, and by Saturday he was able to put out his tongue, which was dead and motionless. On Monday he could speak a little, and on Tuesday he could speak

TABLE 1. *Electricity Comes of Age Leading to its Application to the Treatment of Voice Disorders*

1746	Pieter van Musschenbroek developed the Leyden Jar to store energy produced by electrostatic generator.
1737–1798	Luigi Galvani discovered that a dead frog's leg will move when in contact with two metals and this led to the idea of animal magnetism.
1816	Alessandro Volta (1745–1827) discovered that the charge was the result of the relationship between metal, acid, and body fluids leading to the development of the battery.
1831	Michael Faraday (1791–1867) discovered electromagnetic induction (faradic coil).
1844	Carlo Matteucci described the theory of counter-currents, continuously flowing direct current generated by injured tissue. He applies this to treatment of muscular paralysis.
1849	The German Emil Du Bois Reymond formulated the law of electrical muscle stimulation, finding that stimulation of any part of a muscle impacted the whole and first used induction coil for muscle stimulation. Together with the work of Matteucci, this lead to the discovery of muscle action potentials.
1855	The French physiologist Guillaume Benjamin Amand Duchenne mapped ''motor points on the body.''
1857	Hugo Ziemssen expanded mapping to the face, head, and neck. He described in great detail how the electrification of the muscles of the face revealed the underlying connections.
1863	Following the development of the illuminated laryngoscope, Morell MacKenzie began to treat voice disorders through the direct application of electrotherapy to the vocal cords.

as well as every''[4] (Quoted from ref. 6, p.109). Both of these cases look at the underlying ''cause'' rather than the phenomenology of the voice, though in both the loss of voice or speech was the primary symptom that demanded electrification. In both, voice/speech was restored.

Notable about these early applications is the detailed accounts of the physics of electricity and the technology of generating electricity that dominate even Wesley's popular handbook. The science is there as much to provide the scientific claim for the therapy as to explain its application and function.

This is particularly true of the second age of electricity. Iwan Rhys Morus, the best historian of electricity, notes that the claims of the electrotherapist rest to no little degree on the claims of electrophysiology.[7] That is, the empirical and theoretical science of anatomy provided the bono fides for all of the therapeutic interventions. But this was true from the very beginning of electrotherapy.

Once electricity could be tamed, the electrical properties of muscles began to reveal themselves. These discoveries led in part to further technological developments. Galvani identified the movement of the muscles in a frog when it came in contact with two metals (brass and iron).[8] The galvanic (direct) currents so produced were seen as a ''natural'' phenomenon inherent to the very composition of the body. With the discovery by Alessandro Volta in 1816 of the ''voltaic pile'' (battery), the induced currents could be mastered in ways that static electricity never was. Michael Faraday developed the electromagnetic induction (faradic coil) or alternating current, beginning the ongoing debate as to which method of electrical generation is better, faradic (alternating current) or galvanic (direct current).

The work of Carlo Matteucci, Emil Du Bois Reymond, and others lead to the discovery of muscle action potentials by the middle of the 19th century.[9,10] The French physiologist Guillaume Benjamin Amand Duchenne, in 1855, continued the investigation of the points on the exterior of the body, which would trigger deep muscular reactions when stimulated with ''localized faradization.''[11] For him, this was a central leap in the potential physical therapy of the body. This discovery led to a wide-ranging therapeutics of the body through the identification of trigger points from which induced currents would move the muscles deep in the body.

Reports of cures using either faradic or galvanic current began to emerge. In 1857, the German physiologist Robert Remak undertakes the cure of stammering in a 12-year-old boy who ''after thirteen treatments had all but stopped stuttering.''[12] Virtually all of the therapists are concerned more with what type of electricity and the locations of treatment than any measure or explanation of the relationship between outcome and therapy.

Following Duchenne's model and Remak's therapeutic claims, Hugo Ziemssen, then at the University of Greifswald, turned to the study of the anatomy of the head and neck. In his 1857 comprehensive handbook of electrotherapy, Ziemssen describes in great detail how the electrification of the muscles of the face reveals the underlying connections.[13] Here, he provided a corrective to Duchenne's rather complex and contradictory model of how the facial muscles worked.[11] Ziemssen, in anticipation of work later in the century, is able to create the effect of the expression of emotions by electrifying specific groups of muscles to make his subjects seem to be angry or be fearful.[13]

Ziemssen does not make specific applications of this knowledge for head and neck therapy (except to note that the use of electricity to ''shock'' someone out of a coma due to CO_2 poisoning).[13] ''Shock therapy'' remains a standard technique throughout an age obsessed with people being buried alive. Remember Edgar Allen Poe's ''The Fall of the House of Usher'' (1845). It is the forerunner of electric cardiac defibrillation developed by William B. Kouwenhoven in the 1950s and 1960s. This then, in turn, led to the development of the electrical pacemaker, now used experimentally for vocal fold paralysis.

Building on this new association of the physics and physiology of electricity, as was the case in each of the earlier ages, therapists immediately began to apply their knowledge to the cure of the body, including that of the head and neck. Once specific muscle groups of the head and neck were identified and could thus be ''manipulated'' by the application of electricity, a new electrotherapy of the voice was possible. Inherently more ''scientific'' than that of the 19th century, as it based its

claims on the newest science of electricity, most of these approaches expressly linked (and explained) their versions of the new science of electrophysiology to therapy. Thus, Harry Lobb, building on the work of Duchenne, presents in the Proceedings of the Royal Society in 1863 the therapy for ''paralyzed muscles'' through the application of electricity.[14] His argument is to distinguish ''paralyzed'' from ''healthy'' muscle groups, but he actually proposes that this act will stimulate and activate the paralyzed muscles.

The single individual who did more than any one else to apply such mixed scientific and empirical approaches to the voice was Morell MacKenzie (1837–1892). He studied medicine in London, Paris, and Vienna; in 1859 he visited Johann Nepomuk Czermak in Pest where he was exposed to the first medical use of the new, illuminated instrument, the laryngoscope. (It had been invented in 1854 by the singing teacher Manuel Garcia, who from 1848 to 1895 taught at the Royal Academy of Music in London, to explore the ''normal'' voice.) When MacKenzie returned to London, he began to use it and won the Jacksonian Prize of the Royal College of Surgeons in 1863 with a treatise ''On the Pathology and Treatment of the Diseases of the Larynx'' illustrated for the first time with images taken from the laryngoscope. He helped found the Throat Hospital in Golden Square in 1863. Later in his career as the most famous laryngologist in Europe, he was embroiled in the misdiagnosis of Friedrich III (the Emperor of Germany) who then died of throat cancer in 1888 under his care. But in 1863, under the influence of Ziemssen's anatomical work cited at the opening pages of the book, he turned to the treatment of voice disorders through the direct application of electrotherapy to the vocal cords.[15]

MacKenzie was not shy about making precisely those claims for cure found in the works of Remak and earlier electrotherapists. Now, however, he could provide an empirical proof, his laryngoscopic pictures, to show the efficacy of electrotherapy, now delivered directly to the vocal cords. He saw all ''nervous afflictions'' of the larynx as either those of the motor or sensory system.[15] To treat these, one needed to learn where and how to apply currents directly to those parts understood as being affected. He provides clinical diagnosis of a wide range of vocal problems. For example, he discusses ''bilateral paralysis of the adductors of the vocal cords,'' which he ascribes to either ''debility or hysteria.''[15] He moves to the treatment ''which is almost always successful. This is the direct application of electricity to the vocal cords.''[15]

There is an ancient association between the loss of speech (globus hystericus) and hysteria, which reappears in the 19th-century revitalization of hysteria as a diagnostic category.[16] Hysteria in the 19th century is defined in conflicting ways; there are theories that place hysteria in the realm of neurological disorders (as the result of physical trauma) and those who see it as a psychological disorder. The discussions of hysteria and the voice assume a physiological basis for hysteria. There is, however, a gendered quality to these diagnoses, which is inherent in the general 19th-century use of hysteria as a diagnostic category, as Sigmund Freud learned in 1886 when he tried to speak of ''male hysteria.''[17] As late as 1908, Wilfred Harris at St. Mary's Hospital in London, notes that ''hysterical aphonia is most commonly met with in young women, and is apt to recur at various times, like other hysterical symptoms. If of recent onset, it can often be cured at once by electrical treatment, though the faradic current will be much better for this purpose than the galvanic.''[18] MacKenzie initially places one pole of the direct current ''laryngeal electrodes'' (designed by him) externally and the other ''within the glottis.'' The pole is charged with a ''succession of short rapid shocks'' and applied three or four times at each treatment. ''The sudden restoration of the voice in some cases, after one application of electricity, indicates that the curative influence in these instances is in all probability of an emotional nature.''[15] He treats (by 1868) more than 200 such cases with success in all but four.[15] He provides a series of cases such as that of ''Miss D, aged 43, with an aphonia of nearly five years standing.''[15] Completely voiceless for 4½ years, she showed ''no signs of hysteria…and her sister informed me that she was not inclined that way.''[15] MacKenzie makes a laryngoscopic examination and sees that ''though on attempted phonation the vocal cords moved slightly towards the median line, they did not nearly approximate.''[15] He diagnosed ''paralysis of the adductors of the

vocal cords.'' After the fourth daily application of electric current to the vocal cords, the voice returns ''very feeble, jerky, spasmodic''; but after 3 weeks of treatments ''it was quite natural.''[15] Further case studies describe paralysis of the tensors also. What is striking in virtually every case is that by being able to return function to the voice through the activation of what are seen (literally) as paralyzed muscles, MacKenzie is able to counter the stigmatizing diagnosis of hysteria (especially in his male patients). In the end if stimulation of the muscles restores speech or strengthens the voice, the etiology must be ''nervous,'' ie, in the neurological or muscular system, not in the psyche. The ''larynx is a musical instrument of extraordinary perfection and charm,'' writes H. S. Bristowe in 1870, ''It is generally considered to be a reed instrument, and is no doubt more related to this than any other variety of musical instrument.''[19] Such a mechanical view of the voice is the result of the radical somatization of vocal therapy; retrain the right muscles and the reeds will vibrate.

By 1869, Mackenzie presents his successful treatment of ''aphonia and the weakness of the voice'' through faradization to the general medical establishment, as an example of how cutting edge therapies complement cutting edge technologies such as the laryngoscope. His central concern is placement: what would be the best placement for the electrodes? He assumes that electrotherapy is effective, as he sees it as the ''natural'' extension of the work of Duchenne and Ziemssen in electrically mapping the muscle trigger points. For MacKenzie, introducing the electrodes into the larynx was a more complicated procedure than merely mapping the muscles as the physician had to use the new technology of the laryngoscope. However, he found that he had a quicker response using his internal placement of electrodes with less ''fatigue and pain.''[20] William Harvey King at Hahnemann Hospital in Philadelphia during 1889 found the external placement of the electrodes on the neck on each side of the trachea preferable in the treatment of laryngeal nerve paralysis. He felt that the internal method was ''certainly annoying to the patient.''[21] What is striking is how the placement of the electrodes, the diagnosis of the pathology, and the specific identification of the patient's vocal use are necessary to define the therapy. These delivery methods and placement continued to be used with minor variations into the early 20th century.[22] Recent advances of microtechnology have even made implantable devises possible.

It is important for us to understand that MacKenzie defines ''paralysis of adductors'' in terms of ''chlorosis, anemia, debility, hysteria, and its cognate affections, recognized by the abnormal elongation of the vocal chords and elliptical opening between them.''[15] ''Electro-puncture'' is used for two types of paralysis of the unilateral or bilateral of the cricothyroid and the lateral adductors. Although the physiology may reflect our contemporary understanding of the nature of the pathology, aided by MacKenzie's use of the laryngoscope, it is clear that his understanding of the etiology and implication of such symptoms is also shaped by the technology available to him.

In trying to determine under what conditions and for which pathologies ''faradization''(electro-stimulation) was used, one must be careful not to presuppose that we easily could translate the diagnostic categories of the time into our 21st-century diagnostic categories. ''Updating'' diagnoses based on the scant information in case histories, whereas tempting, presupposes a continuity of diagnosis which does not exist, assumes that medical terminology has been static, and that there is no cultural context for diagnosis. For example, after Sigmund Freud's rethinking of ''neurosis,'' this term in the early 20th century now refers (at least in the popular language) to a psychological state. However, in the mid-19th century (and for the neurologist Freud) it referred specifically to lesions of the nervous system. During the course of the 19th century, ''nervous afflictions of the larynx'' could mean anything impacted by the nervous system, from true neurological paralysis to what we today consider to be ''conversion disorders.''

In the 1840s, American medicine had also begun to adapt the craze for electrotherapy (or ''Franklinization'' to give an American label) to the treatment of all forms of illness.[23] Applied to ALL somatic pathologies, it is of little surprise that the voice too became a site for therapeutic intervention.[24] MacKenzie's central role in linking therapy of the voice with the ability to ''see'' vocal production shaped the claims of his direct therapeutic method. By the 1870s, such direct interventions had also

become part of the cutting edge treatment of voice disorders in America. Beverley Robinson at Charity Hospital in New York City presented a case of aphonia of 10-month duration cured, as with MacKenzie, by the application of ''faradic current'' to the vocal cords. Again Robinson saw in this and other cases of aphonia an underlying somatic condition. No matter what the etiology, the loss of voice can be remedied ''after one or two applications of electricity.'' As the patient writes him: ''I can talk, laugh, call, read aloud, and use it as other people do without any inconvenience.''[25] Electrotherapy became commonplace in the treatment of American voice and swallowing disorders until the beginning of the 20th century. William Harvey King states in 1889 that both cases of hysteria[21] and damage to the laryngeal nerve[21] can be so treated. He does not advocate the direct application of the electrodes to the larynx as ''the current used is necessarily much weaker'' than in an external application.'' He notes, however, ''hysterical aphonia may be treated in this manner, but the current should be strong enough to produce an unexpected cry.''[21] King's work in electrifying muscles was seen by him to do more than just restore muscle function whether to limbs or voice: ''The whole nervous system seems sometimes to be reorganized. Peevish, fretful children become quiet and cheerful, melancholy is changed to happiness, and stupidity to brightness.''[26] In 1897, he too writes about the perfection of the ''larynx as a musical box.''[27] He wants to retune this ''musical box,'' strengthen the muscles and to heighten the pitch of the voice by means of electrotherapy. Here, he takes direct issue with MacKenzie's purely therapeutic approach to the voice.[27] He sees this as a means of strengthening those muscles of the throat weakened as a ''local neurasthenia,'' a weakness of the nervous system, at the time labeled by its ''discoverer'' the electrotherapist George Miller Beard as early as 1869 as ''The American Disease.''[28] This is the disease of urban, stressful life; the suffering of those unable to keep up with the speed of modernity, whose nervous system collapses under the strain.

Beard, like many of his contemporaries, saw nervous fluid and electricity as interchangeable and associated with a principle of vitality. Thus, pathologies were disequilibrium of nerve force, and electricity was seen as restorative. And what Americans suffer from this? None other than ''professional cultivators of the voice.''[28] ''Any one who has treated neurasthenia knows that physical exercise is good up to a certain degree, but when you undertake to go beyond that point all exercise is injurious and if persisted there will be a collapse. Exactly the same conditions prevail here and are the cause of so many voices breaking down under training.''[28] Here, it is the confluence of ''physicians, scientists, and music teachers'' who must be aware of the need to treat the underlying weakness of the neurasthenic voice before the professional voice user suffers.[28] William Harvey King anecdotally tells of one of his patients referred to him by ''one of the best music teachers in this city'' who had a ''partially paralyzed'' vocal cord, ''the two cords were not drawn to the same tension, and she was unable to produce a note.'' He treated her through electrotherapy and her voice was restored.[27] Following this article, a group of voice specialists discussed King's claims of an electric prophylactic therapy for the voice. They discussed the use of externally applied faradic current for the treatment of laryngitis and the use of electricity as ''a voice tonic.''[27] The consensus was that weak voices need muscular training; since ''phenomenal voices'' represented the ideal forms of musculature.

The argument that all voice conditions have underlying somatic causes and are thus the appropriate venue for electrotherapy becomes a mantra in European laryngology after MacKenzie as well. Wilhelm Erb[30] at Leipzig develops his own suggested therapies, following the lead of Remak and Sigmund Freud's teacher, Moritz Benedikt.[29] In Erb's 1886 handbook, he notes the treatment of laryngeal disorders through ''faradic'' therapy, but concludes with a discussion of the treatment of pure disorders of the vocal cords as in the case of hysteria. Much of the success, he notes, is transitory and demands regular faradic treatment.[30]

The craze for electricity as therapy for nervous diseases, including those of the voice, spread widely. The idea that the body was itself a source of ''natural'' electricity and that the application of electrical current or static electricity has innately therapeutic power became commonplace by the close of the 19th century. All of these innovations

were linked to ''real'' science: the developing understanding of anesthetics or the electric properties of the muscles and the nervous system. But all assumed that there were infinite therapeutic applications for these physiological discoveries. Suddenly the application of mild currents, usually alternating (faradic) current, was the therapy of choice for diseases from neurasthenia to gout to diabetes. Hospitals in the United Kingdom and Germany had full departments of electrotherapy catering to such clients by 1900. They were a further means of justifying the relationship between ''science'' and therapy.[31,32] The primary pathologies being treated were nervous or hysterical aphonia, paralysis of the larynx, impaired phonation, general weakness of the voice often affecting the entire range, esophageal spasms, and difficulty swallowing. Treatment of acute laryngitis and myasthenia gravis were counter indicated.[27] As understanding of muscle physiology improved, the treatment of paralysis with electrical stimulation was undertaken only when muscles remained intact.[33] The techniques used were little different from those developed by MacKenzie. Treatment durations varied from one session for hysterical aphonia to daily sessions diminishing in frequency over several weeks. The stimulation times and methods also varied depending on the type, faradic or galvanic, and the strength of the current.[18,22,34] What is clear from this wide range is that the debates about the use of electrotherapy turned on the nuances of the treatments, not on their efficacy. The assumption is that electrotherapy of the voice is effective, the only question is how best to undertake it.

In France, Granier and Moutier, the voice teachers associated with the Opéra, used such techniques to ''strengthen the singing voice.'' It cured ''fatigue vocale'' and made ''the sustained production of the higher notes more easy.''[35] William Scheppegrell of New Orleans contributes a major chapter on diseases of the throat, ear, and nose to Solomon Solis Cohen and George W. Jacoby's ''alternative'' (nondrug) therapeutic handbook in which he advocates his own form of laryngeal electrode for the treatment of voice disorders.[36] He places the electrodes to ''stimulate the recurrent laryngeal nerve'' and to treat ''obstinate cases mistaken for subacute or chronic laryngitis in actors, lawyers, clergymen, and others who make much use of the voice, and which are due not so much to inflammation as to improper methods of phonation. The causative errors should, of course, receive due attention.''[36]

As late as 1921, Francis Howard Humphris, former head of the Electro-Therapeutics Department of the Third London General Hospital, advocated the placement of electrodes on the outside of the throat to treat ''public speakers and singers'' who ''have great relief when their voice is over-strained.'' He also argues that such treatment has ''in one perfectly healthy singer [raised] the voice … one half-tone each way to its register.''[37] Over and over as such approaches came to be standard, the variables in treatment include the social role of the speaker and its implication of etiology of the pathologies.

Now it is clear that electrotherapy in its many forms was the treatment of choice by the end of the 19th century for a wide range of illness including those of the voice. But there were always dissenting opinions. William Beven in 1842, at the beginning of the electrophysiological era, called such therapies ''another instance of those chimerical fancies of the day, which are perpetually disgracing our profession, and bringing it into contempt with the public; that, like mesmerism, it will meet with a similar fate—to be merely had in memory, and as a tale that were told.''[38] The fact is that it does not vanish but becomes institutionalized with all of its far-reaching therapeutic claims. The wide scale sale of quack ''electrical cures,'' such as the Diaduction Machine patented by Hercules Sanche in 1887 and sold by Sears and Roebuck in their catalogue for $10.00 further drew such therapies into question.[39]

The question had begun to be raised as to why electrotherapy was affective in the treatment of voice disorders. The test case became that widespread malady, hysteria, and its defining symptom, at least for the 19th century, globus hystericus, the constriction of the throat and the absence of the voice. Some, like Charles Darwin in 1872, argued that such symptoms are merely the extension of the ''normal'' emotion of grief.[40] Others, such as the psychologist G. Stanley Hall, saw it as a ''normal'' response to sexual development.[41] As ''normal'' responses, they need little or no treatment.

It was the Viennese neurologist Sigmund Freud who recognized globus hystericus as a central symptom of hysteria but sought a new method for its treatment. For the young Sigmund Freud, hysteria is the ''contrary'' of neurasthenia; it too is a modern disease, but one which has its roots in a trauma of the central nervous system. One of the central symptoms of this new way of seeing hysteria as a result of neurological trauma is the ''well-known … globus hystericus, a feeling referable to spasms of the pharynx, as though a lump were rising up from the epigastrum to the throat.''[42] Yet, Freud is quite aware that hysteria is no way a disease of women, as ''hysteria in males gives the appearance of a very severe illness.''[42] For all of the symptoms of hysteria, electrotherapy was the treatment of choice.

Certainly, the doubts about the efficacy or danger of the application of electricity in all of its forms to the voice were also sensed by the late 19th century.[43] Friedrich Ernst, in his 1899 study of the pathology of the singing voice, refrains from any mention of electrotherapy.[44] By 1897, Sigmund Freud abandoned his view that all of his hysterics suffered from sexual trauma. He also abandoned the use of electrotherapy, seeing it as the result of suggestion and as a ''pretence treatment.''[42] He continued to treat voice and vocal problems, but through psychoanalytic interventions as he understood them as psychogenic. Freud was among a growing number of therapists in the 1890s, who came to judge electrotherapy as unsuccessful and yet their powerful associations with the newest technologies of the dynamo and mass electrification made it remain seductive.[45]

This anxiety about the efficacy of electrotherapy came to be shared by the professional electrotherapists. Samuel Sloan (1911) in a presentation to the electrotherapeutical section of the Royal Society of Medicine London, writes: ''The successful electro-therapeutist must be first of all a skilled physician with a wide experience of men and women in health and in disease; for it is a diagnosis not of the disease but of the patient which is all-important…. failures in electro-therapy… are due to neglect in the diagnosis, not of the disease, but of the cause.''[46] This marks both the high point of the acceptance of electrotherapy in the medical profession and the moment when it begins to be questioned. Over the next four decades it would vanish so completely that ''electro galvanic machines'' came to be relegated to museums rather than therapy rooms.

By 1969, electrotherapy had become an adjunct of physiotherapy and the standard handbook of the day while speaking of diathermy, electroshock, ultrasonic and ultraviolet therapies avoid any discussion of the treatment of the larynx or the voice.[47] The ''tingle'' effect, the key to the psychological function of electrotherapy, had ceased to be associated with medical treatment as electricity became a commonplace of Western cultural experience.[48]

Between the end of WWI and the mid-1960s, mention of electrical stimulation for treatment of voice disorders all but disappears. Interest resurfaces in the mid-1960s in Russia, where electrotherapy as an artifact of the persistence of older, German medical traditions, had still persevered. Indeed with the wide acceptance of the work of Yakov Kots and his Soviet coworkers beginning in the 1970s, electric stimulation therapy for muscle strengthening has become a commonplace in sports medicine and beyond.[49] It is of little wonder that it was also applied in the USSR to a wide range of pathologies including those of the voice. By the 1960s, Soviet researchers reported the use of sinusoidal low frequency currents on patients with vocal fold paralysis and parses.[50]

As the general acceptance of electrotherapy and electrostimulation increased in the West with perceived improvement of technology, the Russian model, an artifact of Soviet medicine's conservative retention of older German models, came to infiltrate Western approaches to voice therapy. Again placement becomes central to discussions of efficacy. From the earliest applications, electrical stimulation was administered either by externally applied electrode or by electrode internally placed into the muscle. Since the 1960s and the reintroduction of electrotherapy, several different terms for electrical stimulation have been developed. These include functional electrical stimulation (FES), neuromuscular electrical stimulation (NMES or FNS), and electrical pacing (laryngeal pacemakers). Such therapy is used to effect muscle strengthening, synchrony of firing, and force of contraction.[51] Many of these use newly developed technologies, such as the cardiac pacemaker, as

their models. More recently, functional neuromuscular stimulation (FNS) has been advocated to restore activity to a denervated muscle system. In the late 19th and early 20th century, following the work of Duchenne, it was understood that electrical stimulation was only efficacious for muscles that were neurologically intact. Electrical stimulation was thought effective only in cases of preserved nervous control where the patient exhibited efferent and afferent of muscle activity, incomplete loss of function of executive organ, and sufficient joint mobility for movement. With these caveats, it was believed that there was a potential for partial and sometimes complete recovery of movements.[52] Most recent applications use electrodes inserted into the muscles (intramuscular) and an indwelling controller like a pacemaker to provide the stimulation either under patient or automatic control. Again the true innovation lies not in the underlying theory, but in the greater sophistication of technology coupled with increased knowledge of the specific anatomy of the laryngeal musculature (Table 2).

In the West, interest in the electrotherapy of the larynx seems to have reappeared in the 1970s and 1980s. It was David Zealear and Herbert H. Dedo who in 1977 introduced the concept of electrical stimulation of laryngeal muscles beginning with a series of animal experiments derived from Wladimir T. Liberson's ideas on functional electrotherapy for ''foot drop.''[53,54] There followed a series of animal studies on the use of electrical stimulation in the regulation of paralyzed laryngeal muscles by means of implants.[55–58] Unlike their predecessors 100 years earlier, they had improved understanding of vocal physiology and function as well as improved technology available to them to charter the impact of their use of electricity in the stimulation of the muscles. As Michael Broniatowski and his collaborators had noted in 1985, progress in the field was only limited by the available technology.[53] How very much like the debates about electrotherapy in the 19th century. The use of implantable laryngeal pacemakers quickly became a ''hot'' topic of research.

By the early 1990s, animal research was sufficiently advanced to permit human studies; it suggested the possibility of FES for managing peripheral neuromuscular deficits, including bilateral vocal fold paralysis and spasmodic dysphonia.[59] Implantable devices seemed a possibility as vagal nerve stimulation for treatment of epilepsy had been introduced in 1990. In 1996, Zealear et al[52] published a case study on the feasibility of the use of electrical pacing in a human larynx using needle electrode to locate and pace the posterior cricoarytenoid. They wanted to determine whether electrical stimulation of posterior cricoarytenoid could produce functional adduction of vocal folds in pace with inspiration. Initial results were positive.

Since the beginning of this century the pace of research has continued to increase. Technological impediments including the relative small size of the muscles being stimulated made electrode placement difficult. There was the ongoing difficulty of the corrosion of the hardware. There was the difficulty of matching the pacing to the need of the patient as opposed to the demands of the pacemaker. Researchers found that it was difficult to prevent the spreading of current to adjacent muscles, given our still limited

TABLE 2. *Research and Clinical Applications and Trends in Electrical Stimulation Since 1990*

		Dysphagia	
Paralysis/Laryngeal Muscle Pacing	**Spasmodic Dysphonia**	**Internal Placement**	**External Electrode Placement**
1993 Lundy	1993 Lundy		
1994 Goldfarb et al			
1996 Zealear			
2001 Grill et al	2000 Bidus	2002 Leelamaanit et al	2001 Freed
2002 Billante et al	2001 Shear and Lee	2003 Burnett et al	2006 Ludlow et al
2003 Zealear et al	2001 Grill et al		
2004 Zealear et al			

understanding of muscle physiology, specifically laryngeal muscle physiology.[60]

Recent advancements in techniques of reinnervation and the increasing ability to miniaturize devices have altered the course of current research and the overall claims of therapy. Researchers have been able to de/reinnervate muscles through surgical interventions. The question is now: Can electrical stimulation positively affect full recovery without synkinesis [the aberrant regeneration of nerve fibers]? In 2001, Grill et al suggest that NMES for bilateral vocal fold paralysis preserved muscle conditioning until reinnervation could take place, following the implantation of electrical pacing devices in the posterior cricoarytenoid.[61] They found that synkinesis did take place interfering with voluntary movement.

An incomplete understanding of the complexity of the neuromuscular structure of the larynx may explain the complex response to electrical stimulation. Zealear and Billante (2004) report the work of Sanders et al who show that there are functional compartments to the muscles.[62] Their evidence of two or three functional compartments is based on the presence of fascial barriers, differences in fiber direction, and site of insertion of the posterior cricoarytenoid, thyroarytenoid, and cricothyroid muscles. They found this further supported by the biochemistry of the muscles, fiber types, and directions. Indeed, even with such innovations in our understanding of the anatomy of the musculature, it seems that branching patterns are variable among individuals. The significance of this finding is that each muscle is not a single entity, but rather part of a functional complex. Innervation patterns were also discovered to be more convoluted. For example, the vocalis muscle appears to receive some innervation by the external branch of the superior laryngeal nerve and the recurrent laryngeal nerve. As a result of this complex innervation and compartmentalization, a higher level of control of individual functions is possible. Paralysis may occur when either synkinesis or dysfunction occurs. Dysfunction may be now redefined as appropriate but inadequate reinnervation. Reinnervation may be inappropriate if synkinesis occurs, resulting from an inadequate number of regenerating neurons reaching their endoneurial conduits.

Experimental results for treatment of spasmodic dysphonia by electrotherapy have been more limited. In addition to the mention by Lundy,[59] Bidus et al[63] report reduction in the severity of symptoms with severe abductor spasmodic dysphonia patients using a temporary wire electrode placed in the thyroarytenoid and lateral cricoarytenoid muscles. Sheer and Lee in 2001 found that combining electrical stimulation with acupuncture reduced the severity symptoms in patients with adductor spasmodic dysphonia.[64] Grill et al found that NMES of the thyroarytenoid muscle in patients with adductor spasmodic dysphonia reduced symptoms when stimulated with NMES.[61] However, technological problems with electrode placement into a single muscle and timing were noted and long-term outcome studies have yet to be undertaken on a larger sample of patients.

The focus of this article is primarily on the use of electrical stimulation on vocal fold function in the treatment of voice pathologies. However, the overlap of function of the laryngeal structures and the recent controversy about the use of VitalStim (Chattanooga Group, Chattanooga, TN) for treatment of swallowing with reported secondary effects on voice disorders leads us to mention briefly current applications of electrical stimulation in dysphagia research and therapy. As such a conflation was a commonplace in the electrotherapy of the 19th century, it may be constructive to examine contemporary therapies in this light.

At the beginning of the 20th century, H. L. Jones in 1904 recommended using statical charging as a valuable treatment for esophageal spasm and difficulty in swallowing.[34] At the very end of the century, the experimental use of electrical stimulation for treatment of dysphagia has again been reported. Marcy Freed began to use electrical stimulation in dysphagia therapy in 1995. Freed received the United States Food and Drug Administration approval to market her VitalStim device in 1997.[65] She published a controversial[66] study in 2001, comparing the efficacy of electrical stimulation to thermal stimulation for dysphagia in 110 stroke patients.[67] She reports that the electrically stimulated patients appeared to do better than the thermal stimulated patients. However, Coyle calls into question the general methodology of the study including

randomization of patients, rater reliability, and lack of sufficient information to replicate the study. In the previously mentioned review article, Grill et al in 2001 report that stimulation of mylohyoid and thyrohyoid together improved laryngeal elevation more than did stimulation of the individual muscles.[61] They also noted that percutaneous unilateral stimulation seemed to create an effect bilaterally implying sphincter-like relationships of the laryngeal muscles. Leelamanit et al (2002) tested the hypothesis that synchronous contraction of the thyrohyoid muscles would improve dysphagia secondary to reduced laryngeal elevation.[68] Of 23 patients, 20 improved after the first round of treatment. Six patients with initial improvement relapsed at 2 and 9 months, but were restimulated with good results. As with Freed, electrode placement was external. A recent study of eight patients with a history of aspiration by Ludlow et al in 2006, used the transcutaneous VitalStim electrodes and protocols.[69] The only motoric effect of surface electrode stimulation with the specific electrode placement used, was depression of the hyoid. However, they found that patients with the greatest degree of hyoid lowering during motor levels of stimulation at rest had the greatest improvement in swallowing with the same levels of stimulation. Findings suggest that patients with little of no ability to produce laryngeal elevation might be put at risk for aspiration if electrical stimulation was used to depress the hyo-laryngeal complex.[69] Therese A. Burnett (2003) used monopolar electrodes inserted in the mylohyoid, thyrohyoid, and geniohyoid muscles to determine which would produce the greatest laryngeal elevation in normal males. Their findings were inconclusive. They found that ''no one muscle or muscle pair achieves the greatest laryngeal elevation in all individuals and that no one muscle or muscle pair achieves the greatest laryngeal elevation in all individuals.''[70] To date, as was the case a 100 years before, results are either inconclusive or there was no reported change.

Anecdotal evidence of the success of electrical stimulation for the treatment of dysphagia, primarily with external electrode placement, abounds. Recently, there have been additional anecdotal accounts of improved vocal quality with electrical stimulation. This seems to be the case particularly with patients with Parkinson's disease. However, some speech therapists also claim to have had success using electrical stimulation (specifically VitalStim) for the treatment of benign vocal fold lesions. Based on these claims, the American Speech-Language and Hearing Association's special interest Division 3 Voice and Voice Disorders has drafted a document reminding members that there currently are no recent clinical outcome studies indicating that electrical stimulation has any validity for voice therapy.[71] It is interesting to note that the major outcome of electrical stimulation in the 20th and 21st centuries is not new and innovative therapies, but rather an increase in out knowledge of neuromuscular physiology. Historical perspective is important, not only to contextualize current trends, but also help to pose new questions and revise expectations.

The entire history of electrotherapy of the voice and the larynx is a chain of innovation, therapeutic applications, newer innovations, newer therapeutic applications, and the gradual abandonment of approaches no longer seen to be efficacious.[72] With the reappearance of electrotherapy as an ''innovative'' therapy over the past decade, only long-range outcome studies will show whether the abandonment of such approaches a 100 years ago was correct or not. This article has shown that new technological advances in electrical stimulation methods have enhanced our understanding of the physiology of the vocal folds, but like our colleagues in the 20th century, electrical stimulation as an effective therapeutic intervention is still elusive.

REFERENCES

1. Hedley WS. *Therapeutic Electricity and Practical Muscle Testing*. Philadelphia, PA: P. Blakiston's Son and Co.; 1900.
2. Franklin B. *Experiments and Observations on Electricity.* London: David Henry; 1749.
3. Shah SB, Chung JH, Jackler RK. Lodestones, quackery and science: electrical stimulation of the ear before cochlear implants. *Am J Otol*. 1997;18:665–670.
4. Wesley J. *Primitive Physic: An Easy and Natural Method of Curing Most Diseases*. 14th ed. Bristol: William Pine; 1770.
5. Wesley J. *The Desideratum: Or, Electricity Made Plain and Useful by a Lover of Mankind, and Common Sense*. Bristol: W. Pine; 1771.

6. Lovett R. *The subtil medium prov'd, or, that wonderful power of nature … which they call'd sometimes æther, but oftener elementary fire, verify'd: shewing, that all the distinguishing and essential qualities ascrib'd to æther … are to be found in electrical fire… : giving an account of the progress and several gradations of electricity, from those ancient times to the present*… London: Printed for J. Hinton …, W. Sandby …, and R. Lovett, at Worcester; 1756.
7. Morus IR. Marketing the machine: the construction of electrotherapeutics as viable medicine in early Victorian England. *Med Hist*. 1992;36:34–52.
8. Pera M. *The Ambiguous Frog: The Galvani-volta Controversy on Animal Electricity*. Princeton, NJ: Princeton University Press; 1992.
9. Carpue JC. *An Introduction to Electricity and Galvanism: With Cases, Shewing their Effects in the Cure of Diseases: To which is Added, a Description of Mr. Cuthbertson's Plate Electrical Machine*. London: A. Phillips; 1803.
10. Matteucci C. *Traité des phénomènes électro-physiologiques des animaux*. Paris: Fortin, Masson; 1844.
11. Duchenne GBA. *De L'Electrisation localisée*. Paris: J.B. Baillière et fils; 1855.
12. Remak R. *Galvanotherapie der nerven- und muskelkrankheiten*. Berlin: A. Hirschwald; 1858.
13. Ziemssen H. *Die electricität in der medicin*. Berlin: August Hirschwald; 1857.
14. Lobb H. On the contractility of healthy and paralysed muscles as tested by electricity. *Proc R Soc Lond*. 1862;12: 650–651.
15. Mackenzie M. *The Treatment of Hoarseness and Loss of Voice by the Direct Application of Galvanism to the Vocal Chords*. London: T. Richards; 1863. all references here are to the second, enlarged edition;
    Mackenzie M. *Hoarseness, Loss of Voice, and Stridulous Breathing, in Relation to Nervo-muscular Affectations of the Larynx*. London: John Churchill & Sons; 1868.
16. Gilman SL, King H, Porter R, Rousseau G, Showalter E. *Hysteria Beyond Freud*. Berkeley, CA: University of California Press; 1993.
17. Libbrecht K, Quackelbeen J. On the early history of male hysteria and psychic trauma: Charcot's influence on freudian thought. *J Hist Behav Sci*. 1995;31:370–384.
18. Harris W. *Electrical Treatment*. London: Cassell and Company; 1908.
19. Bristow JS. Lumleian lectures on the pathological relations of the voice and speech. *Lancet*. 1879;113:505–507.
20. MacKenzie M. Faradisation and galvanism in aphonia and weakness of the voice. *Practitioner*. 1869;2:148–152.
21. King WH. *Electro-therapeutics or Electricity and Its Relation to Medicine and Science*. New York, NY: AL Chatterton & Co.; 1889.
22. Jacoby GW, ed. *Electrotherapy, Book 2, Diagnosis: Therapeutics*. In: Cohen SS, Jacoby GW, eds. *A System of Physiologic Therapeutics*, Vol. II. London: Rebman Ltd.; 1901.
23. Paige A. *The Electropathic Guide: Devoted to Electricity and Its Medical Applications*. Boston, MA: Damrell & Moore; 1849.
24. When electricity was a panacea. *Ala Med*. 1991;61:32.
25. Robinson B. Aphonia of ten months' duration from paralysis of the arytenoideus proprius muscle, with concomitant heart disease. *Am J Med Sci*. 1877;73:123–126.
26. King WH. The clinical uses of electricity in muscular development. *Transactions of the Annual Meeting—National Society of Electro-Therapists*. 1894;2:73–79.
27. King WH. The development of the higher vocal register by electricity. *J Electrother*. 1897;15:21–32.
28. Beard GM. *The Medical Use of Electricity, with Special Reference to General Electrization as a Tonic in Neuralgia, Rheumatism, Dyspepsia, Chorea, Paralysis, and Other Affections Associated with General Debility, with Illustrative Cases*. New York, NY: W. Wood; 1867.
29. Benedikt M. *Elektrotherapie* 1868;. reprint: Nendeln: Kraus Reprint; 1981.
30. Erb W. *Handbuch der elektrotherapie*. Leipzig: F.C.W. Vogel; 1882.
31. Morus IR. *Frankenstein's Children: Electricity, Exhibition, and Experiment in Early-nineteenth-Century London*. Princeton, NJ: Princeton University Press; 1998.
32. Bryan BA. *Wilhelm Erb (1840-1921): Electrotherapeutics and scientific medicine in 19th-century Germany* [dissertation]. London: University College; 1966.
33. Bigelow H, Massey GB, eds. *An International System of Electro-therapeutics*. London: Henry Kimpton; 1902.
34. Jones HL. *Medical Electricity: A Practical Handbook for Students and Practitioners*. 4th ed. London: H.K. Lewis; 1904.
35. Albert-Weil E. *Manuel D'Électrothérapie et D'Électrodiagnostic*. Paris: Félix Alcan; 1906.
36. Scheppegrell W. The application of electricity in diseases of the nose, throat, and ear. In: Jacoby GW, ed. *Electrotherapy, Book 2, Diagnosis: Therapeutics*. In: Cohen SS, Jacoby GW, eds. *A System of Physiologic Therapeutics*, Vol. II. London: Rebman Ltd.; 1901:239–266.
37. Humphris FH. *Electro-therapeutics for Practitioners*. London: Henry Frowde and Hodder & Stoughton; 1921.
38. Beven W. An inquiry into the truth of the electrical nature of the nervous principle. *Lond Med Gaz*. 1842;29:173–176.
39. van Dulken S. *Inventing the 19th Century: The Great Age of Victorian Inventions*. London: British Library; 2001.
40. Darwin C. *The Expression of the Emotions in Man and Animals*. London: J. Murray; 1872.
41. Hall GS. *Adolescence: Its Psychology and Its Relations to Physiology, Anthropology, Sociology, Sex, Crime, Religion and Education*. New York, NY: D. Appleton and Company; 1904.
42. Freud S. Standard Edition of the Complete Psychological Works of Sigmund Freud. 24 vols. In: Strachey J, Freud A, Strachey A, Tyson A, eds. London: Hogarth; 1955–1974.
43. Moran R. *Executioner's Current: Thomas Edison, George Westinghouse, and the Invention of the Electric Chair*. New York, NY: Knopf; 2002.

44. Ernst F. *Die krankheiten der nase und des halses: ihre beziehungen zum gesammtorganismus und ihre bedeutung für die singstimme: zehn allgemeinverständlich vorträge*. Berlin: Adolf Köllner; 1899.
45. Hirschmüller A. *The Life and Work of Josef Breuer*. New York, NY: New York University Press; 1989.
46. Sloan S. Success or failure in electro-therapy: a consideration of some of the causes read at a meeting of the Electro-Therapeutical section of the Royal Society of Medicine on April 21, 1911. *Lancet*. 1911;178:15–17.
47. Scott PM, ed. *Clayton's Electrotherapy and Actinotherapy: A Textbook for Student Physiotherapists*. London: Baillière Tindall & Cassell; 1969.
48. Fishlock D. The tingle factor. *New Sci*. 1994;144:58–59.
49. Ward AR, Shkuratvoa N. Russian electrical stimulation: the early experiments. *Phys Ther*. 2002;82:1019–1030.
50. Iakovleva IIa, Iliutovich GM, Iuvalova ND. On the use of sinusoidal low-frequency modulated currents in vocal disorders in patients with paralysis and paresis of the laryngeal muscle [Russian]. *Vestn otorinolaringol*. 1965;27:93–98.
51. Higgens MJ, Eaton CO. Nontraditional applications of neuromuscular electrical stimulation. *Athletic Ther Today*. 2004;9:6–10.
52. Zealear DL, Rainey CL, Herzon GD, Netterville JL, Ossoff RH. Electrical pacing of the paralyzed human larynx. *Ann Otol Rhinol Laryngol*. 1996;105:689–693.
53. Broniatowski M, Kaneko S, Jacobs G, Nose Y, Tucker HM. Laryngeal pacemaker. II. Electronic pacing of reinnervated posterior cricoarytenoid muscles in the canine. *Laryngoscope*. 1985;95:1194–1198.
54. Zealear DL, Dedo HH. Control of paralyzed axial muscles by electric stimulation. *Trans Sect Otolaryngol Am Acad Ophthalmal Otolaryngol*. 1977;84:310.
55. Bergmann K, Warzel H, Eckhardt HU, Gerhardt HJ. Respiratory rhythmically regulated electrical stimulation of paralyzed laryngeal muscles. *Laryngoscope*. 1984;94: 1376–1380.
56. Obert PM, Young KA, Tobey DN. Use of direct posterior stimulation in laryngeal paralysis. *Arch Otolaryngol*. 1984; 110:88–92.
57. Otto RA, Davis W, Betten JR, Downen P, Otto PM. Electrophysiologic pacing of vocal cord abductors in bilateral recurrent laryngeal nerve paralysis. *Am J Surg*. 1985; 150:445–451.
58. Sanders I, Kraus WM, Morel B, Wu BL, Aviv JE, Biller HF. Transmucosal electrical stimulation of laryngeal muscles. *Ann Otol Rhinol Laryngol*. 1989;98:339–345.
59. Lundy DS, Casiano RR, Landy HJ, Gallo J, Ramsey RE. Effects of vagal nerve stimulation on laryngeal function. *J Voice*. 1993;7:359–364.
60. Zealear DL, Billante CR, Courey MS, et al. Reanimation of the paralyzed human larynx with an implantable electrical stimulation device. *Laryngoscope*. 2003;113:1149–1156.
61. Grill WM, Craggs MD, Foreman RD, Ludlow CL, Buller JL. Emerging clinical applications of electrical stimulation: opportunities for restoration of function. *J Rehabil Res Dev*. 2001;38:641–653.
62. Zealear DL, Billante CR. Neurophysiology of vocal fold paralysis. *Otolaryngol Clin North Am*. 2004;37:1–23.
63. Bidus KA, Thomas GR, Ludlow CL. Effects of adductor muscle stimulation on speech in abductor spasmodic dysphonia. *Laryngoscope*. 2000;110:1943–1949.
64. Sheer S, Lee L. Acupuncture for the treatment of adductor spasmodic dysphonia. *Med Acupunct*. 2001;14:20–23.
65. *VitalStim® Fact Sheet*. Chattanooga, TN: Chattanooga Group; 2005. vitalstimtherapy.com. brochure.
66. Coyle JL. Critical appraisal of a treatment publication: electrical stimulation for the treatment of dysphagia. *Perspectives on swallowing and swallowing disorders*. 2002; 11(4):12–14.
67. Freed ML, Freed L, Chatburn RL, Christian M. Electrical stimulation for swallowing disorders caused by stroke. *Respir Care*. 2001;46:466–474.
68. Leelamanit V, Limsakul C, Geater A. Synchronized electrical stimulation in treating pharyngeal dysphagia. *Laryngoscope*. 2002;112:2204–2210.
69. Ludlow CL, Humbert I, Saxon K, Poletto C, Sonies B, Crujido L. Effects of surface electrical stimulation both at rest and during swallowing in chronic pharyngeal dysphagia. *Dysphagia*. 2006;21:1–10.
70. Burnett TA, Mann EA, Cornell SA, Ludlow CL. Laryngeal elevation achieved by neuromuscular stimulation at rest. *J Appl Physiol*. 2003;94:128–134.
71. American Speech-Language-Hearing Association, Special Interest Division 3 (Voice and Resonance Disorders. Regarding the application of surface electrical stimulation as a treatment for dysphonia. Available at: http://www.asha.org/Forums/shwmessage.aspx?ForumID=9229&MessageID=242127.
72. Morus IR. The measure of man: technologizing the victorian body. *Hist Sci*. 1999;37:249–282.