CHAPTER II

A REVIEW OF THE LITERATURE

In opening a literature review that focuses on the artificial larynx and the people closest to it, the text addresses several components within the realm of speech pathology. Following a definition of the artificial larynx, the literature review is organized into five sections: 1) the normal voice mechanism, 2) a historical accounting of the artificial larynx, 3) conditions that would necessitate the use of an artificial larynx, 4) the role of the speech-language pathologist and 5) studies surrounding the artificial larynx devices. Three different techniques or strategies for alaryngeal speech are currently in use by individuals who have lost function of the vocal mechanism. This review considers those devices that are considered artificial larynx devices and does not discuss esophageal speech or tracheoesophageal speech in detail. In an effort to supplement an understanding of the artificial larynx user and the disease process, supporting information such as symptoms of laryngeal cancer and cancer classifications is provided.

Nicolosi et al. (1983) defined an artificial larynx as a mechanical device that creates a voicing signal and replaces the laryngeal function for speech. The authors further define the artificial larynx as:

> An electrical or electronic device that is a battery powered, transistorized vibrator used to create a synthetic voice by producing a continuous buzzing sound. Some

> models are capable of pitch variation. The device is placed snugly against the skin of the neck at a particular anatomical site, which varies with each individual. Such devices are also known as an electrolarynx. A pneumatic artificial larynx is a AU≅ shaped appliance utilizing air pressure; one end is inserted into a tracheal tube and the other is inserted into the mouth to serve as a bypass: expired air vibrates and is carried into the mouth where it is modified into speech sounds by the articulators. A reed artificial larynx is any artificial larynx with a reed serving as the sound source. (p. 16)

Moss (1988) defines the artificial larynx by what it is not. Contrary to lay terminology that can confuse the purpose of the artificial larynx, Moss states:

> It should also be mentioned that the artificial larynx is not a ABuzzer,≅ it is not a AVibrator,≅ not a ATalker,≅ not a ASquawker,≅ and not a ATalk Box.≅ It is an artificial larynx and its job is simply to provide the sound which you will convert into speech. It does the job that your vocal cords used to do. (p. 14)

Blom (1978) explains that electronic larynx devices can be neck or intraoral types. Neck type devices, sometimes known as transcervical devices, are held to the neck and generate a signal that penetrates through the neck and into the mouth for articulation. Intraoral type devices deliver the signal directly into the mouth by way of an oral tube which is placed between the lips or into the oral cavity during articulation.

The Normal Voice Mechanism

As a young fetus approaches the end of his or her first trimester, Aronson (1985) reports that the larynx has taken on the same form that is recognizable at birth.

Anatomically located high in the neck, the larynx slowly descends throughout life. Throughout the life cycle, the larynx serves two very important functions. Broad (1973) indicates that on a primary biological level, the larynx is an elaborate valving mechanism that keeps both food and liquids from reaching the lungs. Likewise, the larynx also keeps air within the lungs so the thorax can be stabilized during strenuous activities such a weight lifting, bowel movement, and childbirth. On a secondary level, the larynx functions to produce sounds that are unique to humans (VanRiper, 1978).

The purpose of this section is not to provide an exhaustive literature review of the normal vocal mechanism. However, for an in-depth review the reader is directed to Willard Zemlin=s (1981) scientific treatise on the subject. Basically, the larynx is a cavity composed of one bone, nine cartilages, and several extrinsic and intrinsic muscles. While the cartilaginous structures form a protective skeletal framework, the muscles serve to anchor, position, and move the larynx (Broad, 1973; McMinn & Hutchings, 1977; Schneiderman, 1983).

The hyoid bone, which is shaped like a horseshoe, forms the upper larynx and provides support for the tongue. Below the hyoid bone, the thyroid is the largest cartilage of the larynx. The thyroid cartilage is typically the most prominent feature on the external throat and is otherwise referred to as the AAdam=s apple.≅ The thyroid structure houses the true vocal folds. The highest cartilage in the larynx is the epiglottis. Located behind the tongue, the leaf-like epiglottis acts like a flapper valve to close off the airway and deflect food during swallowing (Groher, 1992; Logeman, 1983). The remaining paired cartilages are the arytenoid, corniculate, and cuneiform. The arytenoid and corniculate cartilages form a structural attachment for the vocal folds. Shaped like two triangles paralleling each other, the arytenoid cartilages can rotate, slide, and tilt to functionally change the position of the vocal cords (Schneiderman, 1983).

Zemlin (1981) explains that within the thyroid cartilage lies two vocal folds. Each fold is composed of a medial ligament and two lateral muscle groups. Shaped in a horizontal, V-configuration, the open ends fasten to the arytenoid while the pointed end attaches to the thyroid angle. As the arytenoids turn, lift and slide, the tension and approximation of the vocal folds is varied. Broad (1973) indicates that the vocal folds are further apart during inhalation and closest together during phonation or when completely valved shut.

In order for any sound to occur, three major components must be present. These include a power source, a vibrating source, and finally, a resonating source. Zemlin (1981) shows that the anatomical correlates to these components are the lungs, vocal folds, and head/neck respectively. Zemlin further notes that several intrinsic muscles are responsible for the small, delicate movements of the vocal folds. In 1843, Johannes Muller devised the myoelastic-aerodynamic theory (Schneiderman, 1983; Zemlin, 1981). Muller theorizes that the vocal folds are set into motion due to their compressible and elastic qualities and the pulmonary air stream. The theory suggests that the frequency produced by the vocal folds is the result of changes in mass and tension. In support of the mucoviscoelastic aerodynamic theory, Titze (1973) describes a model composed of 16 masses or segments. The model was able to 1) account for voicing in two registers, 2) allow for pathological studies, 3) allow for variations such as pitch breaks and coughing, 4) correlate to physiological parameters, and 5) increase the "naturalness" of voice. Titze explains that each vocal fold is composed of the mucous membrane and the vocalis muscle that are coupled to a taunt vocal ligament. Each fold behaves differently during vibration in both vertical and horizontal motion and phase. The movements of the vocal folds are influenced by internal, external, and dissipative forces. Internal force refers to the neighboring forces of surrounding tissues. External force refer to gravity and aerodynamic factors. Dissipative force refer to changes in glottal flow and losses in the vocal tissue. Along these same lines, Zemlin states,

> Properties of the mucus, mucous membrane, connective tissue, including the conus elasticus and vocal ligament, the muscle tissue, and the boundaries of the vocal folds, all contribute to the mode and frequency of vibration. These properties are regulated primarily by the delicate interplay of the intrinsic laryngeal muscles. (p. 29)

Historic Review of the Artificial Larynx

Several authors (Arnold, 1960; Blom, 1978; Lebrun, 1973; Keith & Shanks, 1986) have described, from a historical perspective, the development of the artificial larynx. Blom (1978), explains that artificial larynx devices have been generally categorized by their powering source and by the way the sound source enters the vocal tract. Within these terms, Blom explains that there are pneumatic and electric or electronic devices. Under the electric and electronic delineation, there are mouth-type and neck-type devices.

Pneumatic Artificial Larynx Devices

The term, pneumatic, indicates that the device obtains its power source from air rather then electricity. Kallen (1934) and Arnold (1960) reported that an air driven artificial larynx was first conceived in 1859 by a Czechoslovakian physiologist named Johann Nepomuk Czermak. Encountering a young 18 year old woman with laryngeal stenosis and a subsequent tracheostoma, it is thought that Czermak had a device made that would have served as the first air driven artificial larynx. According to Lebrun (1973), who was able to translate Czermak=s 1859 foreign manuscript, it was stated that Czermak had hoped to find someone who could construct the prosthesis he had devised. Largely, it is unknown whether Czermak actually had the device created. Regardless of whether or not Czermak ever constructed the prosthesis, the device consisted of a tube and reed assembly which used expiratory air from the tracheostoma. When air passed over the metal reed, a vibration was set into motion that created a tone. Kallen and Keith and Shanks (1986) report that a patient using this type of device was able to exhale air past the reed and into a tube that led to the mouth, and by doing so was able to articulate and produce single syllables.

According to Keith and Shanks (1986), in 1873 a Viennese surgeon named Theodore Billroth along with his assistant, Carl Gussenbauer, performed the first successful laryngectomy. Born on April 26, 1829, on an island in the Baltic Sea, Keith and Shanks report that Billroth showed Alittle early brilliance.≅ Billroth needed tutors and he was slow to comprehend. With encouragement to study medicine from his family, Billroth enrolled at the University of Gottingen where he became interested in physiology and surgical pathology. He graduated in 1852 with a thesis entitled, AThe nature and cause of pulmonary affections produced by bilateral vagel section≅ (Weir, 1973). At age 25, Billroth was appointed at the Langenbeck Clinic where he remained for 6 years studying and publishing. On Christmas Eve, 1859, Billroth was appointed to the Chair of

Surgery at Zurich. Medicine was not Billroth=s only talent however. He studied the viola, wrote musical critiques, and was close friends with Johannes Brahms. In 1867, Billroth accepted the Chair of Surgery at Vienna. While in Vienna, Billroth performed the first laryngectomy. Having some understanding of the need for communication, Billroth and his assistant, Gussenbauer taught their patient to speak using an artificial larynx that was designed specifically for this patient. Keith and Shanks (1986) and Lebrun (1973) believe that instrument maker, Josef Leiter, assisted greatly in developing this first prototype. Lebrun shows that the device made by Leiter was composed of three cannulas or metal tubes. The first tube fit between the trachea and stoma. A hole was situated in the superior portion of the tracheal cannula and, through this orifice, the laryngeal cannula was mounted. The laryngeal cannula created a passage to the pharynx. On the top portion of the laryngeal cannula, a phonatory cannula was mounted. The phonatory cannula housed a metal reed, and on the superior end of the tube a spring loaded trap door served as an artificial epiglottis. Interestingly, the new epiglottis stayed in an open position with the hope that it would close when a swallow occurred. Billroth=s milestone surgery and device application was a demonstration of science and skill.

With translation by Schechter and Morfit (1965), a noteworthy review would not be complete without looking at the intriguing historical surgery according to Gussenbauer (1874):

> The entire procedure of total laryngectomy took Billroth one hour and 45 minutes. The patient, a 36 year old teacher with a tumor below the true vocal cords was first treated with multiple cauterizations and biopsies (microscopic report:

epithelial carcinoma of the larynx). On November 23, 1873 (after preliminary tracheotomy), Dr. Billroth performed a laryngofissure and removed the tumor with scissors and a sharp curette. The main tumor was situated on the left side, so the surgeon was able to preserve the right vocal cord; the wound edges were approximated with tape. On the second postoperative day the patient began to have septic temperatures, and infection developed in the wound, which was treated with a preparation containing silver nitrate; on the seventh postoperative day the patient was up and about, and two days later a high degree of dyspnea developed. The wound was reopened and examination revealed that the growth had recurred. In an attempt to curette the larynx, Dr Billroth reopened the wound, but discovered that the malignant growth had invaded the cartilage. The patient was awakened, informed of the necessity to remove the larynx and again anesthetized. The technique consisted mainly in dull dissection of the larynx on both sides while the assistant exerted a pull on the larynx. The trachea was divided just below the cricoid, the larynx pulled forward and up, and dissected from the anterior wall of the esophagus; the thyroid membrane was divided last. The anesthesia was not sufficient, and the operative procedure was frequently interrupted by strong coughing spell during which blood in rather large amounts was expelled from the trachea. The bleeding was controlled by pressure with large sponges. . . Fortunately, the patient escaped all secondary complications, such as shock, aspiration, pneumonia, mediastinitis, sepsis, meningitis, tetanus, and large abscess. The pharyngeal fistula began to close early, and the patient was started on a soft diet on the eighth postoperative day; the gastric feeding tube

> was removed on the eighteenth day. The patient was dismissed on March 3, 1874 after he had learned how to use the artificial larynx device. (p. 465)

The device that Billroth, Gussenbauer, and Leiter used with this early patient was essentially an internal pneumatic artificial larynx.

According to Kallen (1934), the artificial larynx conducted an internal tone through the tracheal opening and into the pharyngeal cavity. A reed inside the prosthesis was set into motion using expiratory breath. This tone could then be transformed into Asounds of articulate value.≅ Since Billroth=s early surgical techniques attempted to preserve the pharyngeal passage, the function of an internal artificial larynx seemed logical. Little knowledge of swallowing function existed, however, and saliva and food fouled the reed mechanism and posed a threat of aspiration (Keith & Shanks, 1986). Unlike Czermak=s earlier prototype, which was an external device, Billroth, Gussenbauer, and Leiter's artificial larynx was placed inside the patient=s body.

Lebrun (1973) and Blom (1978) indicate that several surgeons continued to use internal artificial larynges initially taking after the design of Billroth, Gussenbauer, and Leiter. The internal devices that followed in history were modifications that altered the cannula shape, cannula flexibility and reed materials. Other modifications included obturation, or a plug, in the laryngeal cannula to reduce aspiration and a one-way valve to eliminate finger occlusion of the tracheostoma when speaking.

In 1887 the Journal of Laryngology and Rhinology published the results of the first 104 laryngectomy procedures. Of these cancer patients, it was written that at least 39 percent died of immediate complications within two hours to eight weeks, mostly of pneumonia. Another 21 percent had a recurrence of cancer within an average of six months after the surgery. Keith and Shanks (1986) point out that attitudes regarding laryngectomy were curt and skeptical since so many patients died within 12 months of having the surgery.

Keenly aware of aspiration pneumonia, a German surgeon named Thermistocles Gluck revolutionized the laryngectomy procedure in the 1880's. Arnold (1960) discusses how Gluck=s new surgical procedure eliminated a connection from the trachea to the pharynx. The pharynx was surgically sewn shut and the trachea was attached to the surface of the neck creating a tracheostoma. As a result, food and saliva had no way to enter the trachea and lungs. Gluck=s technique gained popularity and, by the turn of the century, many surgeons had converted to this new procedure. Since the cavity between the trachea and pharynx was no longer present with Gluck=s surgical technique, the internal artificial larynx lost momentum because it no longer had a place to reside in the body. The earlier concept of Czermak=s external artificial larynx returned.

Around 1877, Carl Stork designed an external device for a young girl with laryngeal stenosis. The device consisted of a reed and intraoral tube. Stork=s early design included a rubber bulb that could be squeezed to power the reed. Unfortunately the bulb did not create enough air pressure and Stork thought to harness the tracheostoma air for the device=s power source (Lebrun, 1973). In 1882, Julius Hochenegg deviated from Stork=s design and used a bellows arrangement and a provocative nasal tube. Connected to the bellows by a nasally placed tube in the oropharynx, the patient would operate the bellows under the armpit to speak. The bellows created an air source that powered a vibrating reed. The tone from the reed was transmitted through a tube that entered the

user=s nose and led to the pharynx. When the bellows was activated the patient could articulate sounds for speech (Lebrun).

Other pneumatic devices followed for many decades. Interestingly, Bell Telephone Laboratories and Western Electric (AT&T, 1996) were heavily involved in the research and development of non-electric, pneumatically powered artificial larynx devices. Keith and Shanks (1986) explained that F.B. Jewett, President of the Bell Telephone Laboratories, suggested the development of an artificial larynx. The Bell Laboratories first efforts resulted in a device that used rubber bands as a sound source. Over the course of many years, several other pneumatically powered devices were made by Bell Telephone.

In 1927, E. McKesson submitted an article to the Journal of the American Medical Association which described a device called the Vocophone. The Vocophone was a pneumatically powered device. McKesson explains,

> This instrument enables a patient whose larynx has been removed because of carcinoma to speak with a voice approaching the normal in volume and quality. A neck piece is held in place by means of the collar, to which it is attached by an ordinary collar button. A rubber tube connects the neck piece with the trumpet and a tube from the trumpet conducts the sound into the mouth. To speak, the neck piece is pressed gently against the neck, and air is blown through the trumpet, setting up a sound resembling the normal voice. This sound is conducted into the mouth, where it is formed into words. Some training and practice are

> required to produce the consonants, while the vowels are easily elicited at once. Practice is required to obtain inflection. The general idea is old, but this instrument embodies several new principles which have resulted in a more perfect reproduction of the human voice. Intratracheal tubes which irritate the trachea have been eliminated. A valve permits free inspiration with the instrument in place and reduces the dead space containing exhaled gases and carbon dioxide, which, together with restricted passages of an instrument, have been factors in producing dyspnea with previous appliances. The trumpet embodies an effective method of voice production and amplification by means of a reed which operates easily, requiring little air pressure and volume. The reed is a standardized inexpensive article and may be replaced almost instantly. When not in use the trumpet is carried in the inside coat pocket. The fresh, cool air entering the trachea at the neck is tempered with a certain amount warm air from the pocket, preventing the cough that results from the inspiration of cold air directly into the trachea. (pp. 645-646)

With the advent of electronic devices, which were considered a quantum leap in voice production (Arnold, 1960), pneumatic devices have become scarce in the United States. The pneumatic devices observed in recent years, however, include the Tokyo (Welch, 1997), the Dutch made DSP-8 (Memcom, Co. 1996) and the ToneAire (Communicative Medical, Inc., 1998). While these devices are seldom seen in the United States, their popularity is greater in Asia and developing countries due to their low, non-electric technology, and cost (Salmon, 1996, personal correspondence).

Electrical and Electronic Artificial Larynx Devices: Oral and Intraoral

Many devices used in the 19th century were considered Aintraoral≅ because the voice signal was delivered into the vocal tract by some kind of tube (Blom, 1978). For the purpose of this review, both denture tube and intraoral are discussed in this section.

Lebrun (1973) explains that the first Aelectrolarynx≅ was introduced by Gluck in about 1909. Recall that Gluck was the surgeon who revolutionized the laryngectomy procedure in the 1880's (Keith & Shanks, 1986). Gluck used an Edison type phonograph powered by an electric motor and a small receiver. The Areceiver≅ can be likened to a small speaker that was placed in the patient=s nose or attached to an upper denture plate. Amazingly, Gluck used the recorded voice of a singer to create a signal that was generated by the receiver and delivered into the vocal tract. Lebrun translated Gluck=s German manuscripts which suggested that a relaxation oscillator could replace the phonograph. Other developers including Tait, Kellotat, Cooper, and Pichler also created devices where the signal was produced by an electrical oscillation from an upper denture (Keith & Shanks).

Keith and Shanks (1986) and Lebrun (1973) explain that Pichler=s innovation used a radio transmitter. The patient actually wore an antenna around his or her neck. When the patient exhaled through the tracheostoma, a small pneumatic switch turned on a transmitter that was placed in the patient=s pocket. The transmitter in turn sent a signal to a tiny receiver strategically placed in the upper denture plate. The voice could then be used for speech. Since stoma noise is a distracter according to Salmon (1999a), Pichler=s idea was doubtfully a success since a chief aim of laryngectomee rehabilitation is learning to Aquiet≅ the tracheostoma. Blom (1978) suggests that Pichler=s device was never manufactured. Pickler=s concept did have one merit, however. The devices had no electrical wires entering the mouth. Tait, according to Lebrun, designed a denture-based device that housed an oscillator, speaker, and battery. The device used a pressure sensitive button that was activated by the tongue. A device called the UltraVoice is currently marketed to a limited degree in the United States. The device utilizes a hand-held transmitter and a finger activated on/off/pitch control (UltraVoice, 1999).

Several intraoral devices were creatively, and quite ironically, housed in tobacco pipes in the early 1970's. Since pipe smoking is the cause of the patient=s laryngeal cancer, it seems peculiar that a device would be fashioned accordingly. Keith and Shanks (1986) mentioned and depicted the Italian made, APipa di Ticchioni.≅ (p. 41) This device used an electromagnet to create a tone that was delivered through the stem of the pipe and into the mouth. Another similar device called the Artificial Larynx of North America was also manufactured. Invented by Hennige, who was a laryngectomized electrical engineer, it is said that the Danish made ADanapipe≅ had miniaturized circuitry, a transducer and battery concealed in the bowl of the pipe. An on/off switch and pitch adjustment was located on the side of the pipe (Blom, 1978; Keith & Shanks). According to Lebrun (1973), the device could be easily mistaken for a real pipe.

The first productions of the Cooper-Rand artificial larynx was a denture type device from 1957 to 1972 (Keith & Shanks, 1986). The Cooper-Rand artificial larynx, an intraoral device, was developed in about 1972. This device is comprised of a battery powered oscillator which is connected to finger activated tone generator. The tone generator contains a plastic tube which is placed in the mouth when articulating speech movements. Volume and pitch can be statically set with control dials on the power pack. Although once a popular device, the Cooper-Rand is seldom seen anymore. According to Tom Lennox (1998, personal communication) of Luminaud Corporation, the Cooper-Rand is used more clinically then for everyday use by laryngectomees. This is largely due to intraoral adaptors that can be affixed to neck-type machines, and therefore giving the patient the choice of an intraoral or neck-type device in a single unit (Salmon, 1999b).

Electric and Electronic Artificial Larynx Devices: Neck-Type

Gilbert M. Wright is credited with inventing the first neck-type artificial larynx in 1942 (Arnold, 1960; Blom, 1978; Keith & Shanks, 1978; Lebrun, 1973). Initially designed as a device for sound effects, Wright=s device used a piston to strike a hard membrane. The device was in turn held to the neck and the Asound effects technician≅ could articulate peculiar sound effects. Lebrun wrote that Wright=s ASonovox≅ was used in animated films to give human-like qualities to trains, steamboats, and airplanes. In fact, the Sonavox was used to make the train mysteriously Aspeak≅ in Walt Disney=s ADumbo≅ film. Lebrun explains that Wright developed a special ASonovox≅ for laryngectomees at the National Hospital for Speech Disorders in New York. The device had a battery pack that could be kept in the pocket or in an underarm sling. This design was then turned over to the Aurex Corporation and manufactured from approximately 1942 to 1993 as the AAurex Neovox≅ before the company=s closing (Communicative Medical, 1995). The device used a coil and electrical points to create a pulse. Worthy of mention is that the Neovox instruction sheet explains that the unit can be converted into an intraoral device with accessory AM-550 cap≅ available from the company. The accessory consisted of a hard rubber crutch stub, the kind that is seen on the leg of a chair or crutch to prevent sliding. A hole was drilled in the closed end of the stub and a dental ejector tube was placed in the hole. The entire assembly was then placed on top of the device. When the patient wanted to speak, he or she simply had to place the tube in the mouth, press an activation button, and articulate speech movements. Blom explains that the intraoral adaptor offers good sound production. Other manufacturers including the Ketts Manufacturing Company imitated Wright=s design (Lebrun).

In 1956 the National Hospital for Speech Disorders formed an advisory committee on artificial larynx devices. The committee believed at the time that the transistor should be used to advance the design of electronic neck-type devices (Lebrun, 1973). Under this consideration Barney, Haworth, and Dunn (1959), who worked for Bell Telephone, first reported on a transistorized artificial larynx. The device contained three transistors: two were used to create an oscillated pulse while the third was a power transistor to amplify the signal. Soon to be coined the Western Electric No. 5, this device had a finger operated potentiometer that could adjust pitch inflection during running speech. Men could adjust the frequency range between 100-200 Hz and women could adjust it between 200-400 Hz. The signal was transferred through the neck using a telephone receiver. The device used two 5.2 volt mercury batteries as its power source. In 1964 Bell Telephone created a similar device with a smaller head and less pitch range (Lebrun; Bell Telephone, 1964).

Since its first appearance in the literature, the Western Electric artificial larynx, which later became the AT&T artificial larynx, was the mainstay in much of the artificial larynx writings (Barney et al., 1959; Blom, 1978; Keith & Shanks, 1986; Lebrun, 1973; Lerman, 1991; Zwitman & Disinger, 1975). Bell Telephone largely distributed the Western Electric artificial larynx which could be procured easily and inexpensively (Bell Telephone, 1964, 1978; Blom). With easy availability of these devices, several authors described methods to modify the Western Electric artificial larynx in some way (Blom; Zwitman & Disinger). The Western Electric and AT&T devices are no longer manufactured due to a limited market and poor demand (AT&T personal communication, 1995).

According to Keith and Shanks (1986) and Lebrun (1973), the German made Servox and the American made Romet neck-type devices were introduced in the early seventies. Lebrun explains that the Servox was based on the earlier Wright invention. This may only be partially true. While the Servox used a vibrating Apestle,≅ it also featured a two-step inflection button that allowed for limited intonation during speech. Also known as the AD-model,≅ the Servox featured a light-weight rechargeable battery. In order to charge the battery in the Servox, the battery needed to be removed from the device and placed in a charger for 10 hours. The device was also lighter than its Wright/Aurex comparative. The components of yesteryear=s artificial larynges were heavy and bulky. While the Wright/Aurex design used a bulky mechanical coil and arcing point system to create a pulse, the Servox and Romet devices accomplished the same by using an oscillating circuit and voice coil. This change alone dramatically decreased the weight of artificial larynx devices.

In her description of artificial larynx devices, Rogers (1994) weighed the Aurex to be 11 ounces. Comparatively, the early Servox weighed 9.16 ounces (Lebrun, 1973) and the Romet weighed in at only 5 ounces (Rogers). The point here is that the literature shows a decrease in weight which made artificial larynx devices easier to use. Although further changes have occurred in their design and weight, both the Romet and Servox currently are manufactured and used by laryngectomees (Romet, 1999; Siemens, 1999). The design of these devices, however, have further changed since Lebrun=s description of the Servox and Keith and Shank=s (1986) description of the Romet. According to the 1993 Communicative Medical Care Chronicle, the

Romet changed to an adjustable head that could alter the Asoftness of tone.≅ The device chassis was made from aluminum rather then the heavier stainless steel.

In around 1985, Siemens introduced the German made AServox Inton.≅ Soon to become one of the most popular electronic device, early Servox sales literature (1986), boasted the following:

> The Servox Inton from Siemens . . . tall in quality, small in size. Approximately 4.6 inches long and weighing only 6.5 ounces, the Servox Inton is an incredibly light and easy to use speech device. But its best feature is its superior sound quality. It provides a clear tone that is easy to understand and soft on the listener=s ear, thereby letting you communicate effectively and with ease. This clear sound quality is enhanced by the Servox Inton=s ability to allow you vary the pitch of your speech -- a feature exclusive to the Servox Inton. Two different tones may be generated by means of the two control buttons located on the side of the device. By varying the pitch produced by the Servox Inton, you can emphasize words you want stressed and add a more harmonious quality to any

conversation. The dual automatic charging console lets you recharge the Servox Inton=s battery without removing it from the unit-- a notable convenience. The console recharges the battery, turning off automatically when done. A convenient charging port is also provided for recharging a spare battery. The Servox Inton is encased in a scratch-resistant titanium housing, that protects the device from outside elements and daily wear and tear. A number of optional accessories is available to choose from, including an oral connector, which provides for use of the Servox Inton to communicate immediately after surgery. (p. 1)

Several other devices have followed a similar path based on the literature. Rogers (1994) describes devices including the single tone Jedcom, which later became the Bruce Lectro Larynx. She also describes the SPKR and Denrick, which like the Servox, offered a two-step inflection button.

According to Gene Bresky of Mountain Precision Manufacturing Company (personal communication, July 16, 1999), two single-tone devices are available, the original NuVois and the NuVois-2. Both devices utilize a light weight rechargeable 9-volt battery. While the original NuVois utilizes a simple on/off button, a small volume knob, and a screwdriver pitch adjustment, the newer version offers stepped adjustment of pitch and volume. That is, a single button adjusts the variable settings of volume and pitch on a stepped and static level.

In 1997 Grant viewed a new device called the TruTone. Using the same type of transducer that is used in the Servox, the TruTone differs in that pitch is dynamically altered using a single pressure sensitive on/off switch. Volume can be statically changed by adjusting a dial. Internal components can be adjusted to alter Abase tone≅ and Arange.≅ The term Abase tone≅ refers to the pitch that is produced when the button is initially depressed; Arange≅ refers to preset upper and lower pitch limits (Griffin Laboratories, 1999). Although the TruTone can use a regular alkaline 9-volt battery, the device comes with two 9-volt rechargeable batteries. Grant (1997) reports that those who encounter the device find it more natural sounding than the Servox device.

Other devices are observed in the market place and are noted by their advertising literature. The American made Solatone is a simple, single-tone device (Griffin Laboratories, 1999). The Italian made, Amplicord, is available in two models. The Model 95 offers an on/off switch that turns the device on automatically when it is pressed against the neck. The regular model utilizes a finger controlled on/off switch. (Amplicord Co., 1999). In 1994, Bivona (1994) introduced the American made Optivox. All four of these devices operate on light weight 9-volt batteries.

Most neck-type devices can be easily converted to an intraoral type. While most users press the device on the neck for signal transfer, a minority of patients utilize an intraoral tube. This simple rubber cap and tube assembly delivers the signal directly in the mouth, thus eliminating the need for neck placement. Using this type of arrangement, and like the pneumatic devices, the patient places a sound tube into the mouth while speaking and pressing the on/off button. This attachment may be helpful for patients immediately after surgery or in the presence of excessive scar tissue or swelling (Communicative Medical, Inc., 1999).

Current Trends Of Artificial Larynx Devices

As historically noted, several authors (e.g., Lebrun, 1973; Keith & Shanks, 1986) have described the devices of yesteryear. According to instruction manuals within the last 10 years, the most common new generation of electronic voice aids are lighter and smaller. Figure 1 depicts the electronic neck-type artificial larynx. Actual tone production is accomplished by an electromagnetic plunger that repeatedly strikes a hard membrane or drum. The hard membrane, located in the head of the machine and on the outer side, has contact with the patient's neck. In order to create an oscillated signal, the device automatically turns on and off at a high rate so the plunger creates a cycle of repeatedly hitting the drum. Depending on the speed and force in which the plunger strikes the drum, variations in pitch and volume are controlled. Rather then using the once bulky electronic parts to create an on-off cycle for oscillation, most new style machines use a silicone chip that serves as a timer. These timers are smaller than a penny and weigh less than a gram.

Typically, these silicone timers use very little energy to operate, thus smaller, lighter and more efficient batteries can be used. Some devices now utilize surface-mount electronic components that are extremely light and small. The ability for artificial larynx manufacturers to reduce overall weight and size while maintaining good tone quality is largely the result of micro-electronics. Many patients are at an age where arthritis and muscle weakness is prevalent. Aside from age, Schutt (1986) explains that the laryngectomy surgery itself may leave a patient with weakened upper extremity movement and limited range of motion on one or both sides. When considering these issues, it is not surprising that a light-weight device is easer to hold an operate. For the non-laryngectomee, having to communicate with a hefty machine can be likened to writing with a heavily weighted pencil. The use of space age materials also has improved the current type of machine.

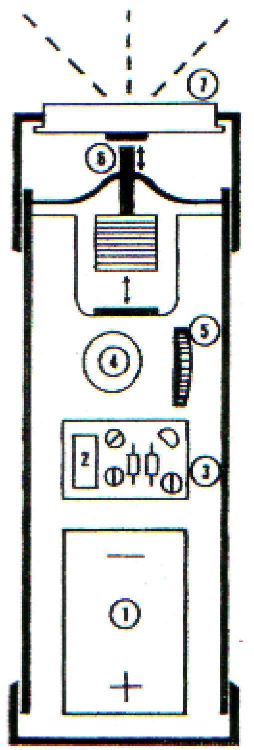

Figure 1. The electronic neck-type artificial larynx and its general components. In the item depicted, 1 = Battery; 2 = Timer Circuit; 3 = Pitch Control; 4 = On/Off Switch; 5 = Volume Control; 6 = Electromagnetic Plunger; 7 = Hard Membrane/Drum.

The incorporation of surface mount and silicone electronics give rise to a machine that is more durable and forgiving to shock damage. New plastic materials and molding techniques offer a device that is easy to hold and manipulate. Controls on several devices now allow for easier operation. Small, low-friction micro-switches and dials are presently used on most models to easily adjust pitch and volume, replacing the trigger or large switches of old style machines. Pitch range can be adjusted quickly to approximate a male or female voice. Most controls are easily accessible on the external case and are user friendly.

Aside from pitch and volume controls, some models allow for limited pitch inflection. Griffin Labs (1999) explains that their TruTone device can change pitch during speech offering a more natural speech. According to the manufacturer (Siemens, 1999), the Servox Inton provides internal adjustments that alter tone decay which is the variance of tone that automatically changes downward after the machine is initially turned on. The Romet, TruTone and SolaTone devices offer a variable head that physically adjusts the distance between the plunger and drum. This feature provides limited fine tuning and, on the Romet, alters the softness of tone.

Power sources for artificial larynx devices also have changed. Once limited to disposable 9-volt radio batteries, mercury batteries, or a heavy battery pack, the electronic voice aids of today offer rechargeable batteries for months of service. Some machines utilize high capacitance, rechargeable batteries while others can use 9-volt rechargeable batteries or alkaline batteries (Communicative Medical, 1999; Siemens, 1999). The most recent innovation is the use of nickel metal hydride batteries.

According to Siemens, these batteries are not as susceptible to over charging and memory problems.

Most artificial larynx devices today come with a charger that rejuvenates a rechargeable battery for many cycles of use. Various factors including volume/pitch settings, actual on-time and battery care essentially will determine the frequency of recharging. Typically these battery chargers will fully recharge a battery in 10-14 hours. Some units offer an automatic shutoff that reduces most problems with over-charging. Some charging units also vary in their ability to charge more than one battery at a time. This feature conveniently allows the patient to carry a fully-charged alternate battery. Like automobiles, the artificial larynges of today have become smaller, lighter, more efficient, and user friendly.

Conditions That Necessitate The Use Of An Artificial Larynx

Total laryngectomees are the primary users of artificial larynx devices (Diedrich, 1978; Lerman, 1991; Salmon, 1978, 1990). Although very small in comparison, others who have lost function of the organic larynx can also benefit from the artificial larynx. Such conditions include ventilator dependency, vocal fold paralysis, tracheotomy, tracheal bypass, laryngeal trauma, and neurological disease. By and large, however, cancer of the larynx is the predominant condition that necessitates the use of the artificial larynx. While total laryngectomy surgery results in the need for a new voicing system, those patients who have had a partial or hemilaryngectomee usually maintain some organic voice and do not require an artificial larynx. While a total laryngectomy refers to the complete removal of the larynx, a partial or hemilaryngectomee leaves one half or more of the larynx intact (Nicolosi et al.,1983).

Statistical Information

Excluding bladder and skin cancers, the American Cancer Society (Landis, Murray, Bolden & Wingo, 1999) estimates that about 1,221,800 invasive cancers will be diagnosed in the United States. Of these cancers, Vaughan, FitzGerald,Vlock, Vergo, and Costello (1996) show that head and neck cancer is a category that includes cancers of the lips, oral cavity, oropharynx, nose, sinuses, neck, ears and salivary glands. More specifically, cancer of the larynx is a component of head and neck cancer (Spiro, 1990). In their discussion on the topic, Vaughan et al. suggest that cancer of the head and neck makes-up five percent of all cancers which is a relatively small number of cases. Approximately 12,000 new cases of laryngeal cancer are diagnosed each year. According to the cancer statistics for 1999, Landis el al. estimated that 3,300 men and 900 women died from cancer of the larynx. Approximately 50,000 laryngectomees currently are living in the United States (ACS, 1993). However, when the lens opens on a global level, there are many more laryngectomees around the world. According to the American Cancer Society (1993), the average age of diagnosis is 63 years with a gender ratio of four males to each female. Doyle (1994) explains that this ratio is closing due to societal and lifestyle changes in women. A shift in society=s acceptance of female smokers, and the subsequent practice of smoking and alcohol consumption, have attributed to this change.

Etiology and Causal Factors Of Laryngeal Cancer

The literature demonstrates overwhelming evidence that smoking is a primary cause in the development of laryngeal cancer (ACS, 1993; Aronson, 1985; Doyle, 1994; Murphy, Morris & Lange, 1997). Alcohol usage however, combined with tobacco, create a deadly and synergistic effect that increase the risk of developing laryngeal cancer (Doyle, 1994; Song & Grandis, 1999). Murphy et al. report that most head and neck cancers are squamous cell carcinomas related to the combination of tobacco and alcohol. The American Cancer Society (1993) indicates that other conditions can play a role in the development of cancer. These conditions include industrial exposure to carcinogens, genetic predisposition, viruses, and accidents. In addition to these factors, Murphy et al. suggest that radiation, inadequate nutrition, and poor oral hygiene can play a role in the development of laryngeal cancer.

Classification Of Laryngeal Cancer

Tumors that develop in the larynx are classified according to their location or site. Aronson (1985) explains that supraglottic tumors are found on the epiglottis, aryepiglottic folds, arytenoid cartilages, false vocal folds and the ventricles. Glottic tumors include those that are located on the vocal fold and/or the anterior and posterior commissures. Subglottic tumors are found below the level of the vocal folds.

The American Joint Commission on Cancer (1988) developed an important set of variables that describe a tumor. Known as the TNM classification system which is an acronym, tumors, including laryngeal lesions, can be described. In this standardized system the T designation indicates the primary tumor size and whether or not it has begun to invade surrounding tissue and structures. The N designation focuses on the lymph nodes and whether or not the primary tumor has affected them. Finally, the M designation addresses metastasis and whether or not the tumor has spread to other organs (Murphy, Morris & Lange, 1997). Typically, the N designation is shown with a number reflecting the number of nodes affected, ie., N0 for zero affected nodes or N2 for two affected nodes. The M designation announces a distant metastases organ, ie., Mpul for metastasis to the pulmonary system (Rice & Spiro, 1989).

Symptoms Of Laryngeal Cancer

The delicate and precise movement of the vocal folds create the sounds that are transformed into speech, singing, laughter, and other vocal output (Aronson, 1985). According to Baken (1987), when growths, benign or cancerous, develop on the vocal fold(s) a change occurs in sound quality. This change in sound quality occurs because added mass upon the vocal folds alters the vibratory response of these tissues. Doyle (1994) explains that tumors, especially ones located in the membranous portions of the glottis, can impinge upon the movement of the vocal folds and alter the acoustic signal. In addition to vocal hoarseness, Murphy et al. (1997) list the following symptoms: ear pain, swollen lymph nodes in the neck, difficulty or painful swallowing, abnormal breathing, coughing up blood, and aphonia or loss of voice. These symptoms can be considered suspect if the patient is a smoker, and especially, a smoker and consumer of alcohol.

The Role Of The Speech-Language Pathologist

Speech-Language Pathologists obtain their undergraduate and graduate training from universities throughout the country. Following the completion of at least a masters degree in communication disorders or a similar area, therapists obtain the Certificate of Clinical Competence (CCC) issued by the American Speech and Hearing Association (ASHA). The CCC is earned following the successful completion of the National Examination in Speech-Language Pathology and a Clinical Fellowship Year. The Clinical Fellowship Year allows the new therapist to practice under the supervision and guidance of a seasoned, certified therapist and the association. In addition to national certification, many states have licensure for speech therapists.

Continuing education opportunities are available from a slim variety of sources. One historic source has been through the International Association of Laryngectomees (IAL). Reeves (1999) explains that the IAL began in 1952 with emphasis on education and support for patients. Later in 1960, the IAL began its first Voice Institute. In the years that followed the Voice Institutes provided evaluations and training to both laryngectomees and speech-language pathologists. Even today, the IAL continues to train patients and therapists. Individuals who have completed training, a written test, and supervision for a year are eligible to become listed IAL Alaryngeal Speech Instructors.

In terms of the adequacy of training, little information is available. The fact that the IAL began and continues to offer the Voice Institutes on an annual level may be indicative that universities are missing important training in this area. The few continuing education slots regarding laryngectomee rehabilitation at the ASHA conventions may also suggest inadequate training (S. Salmon, personal communication, April 4, 2002). Additionally, the amounts new clinicians entering the field who attend the IAL Conventions for continuing education opportunities are decreasing with the influx of the tracheoesophageal puncture prosthesis (J. Shanks, personal communication, July 17, 2002). Reeves (1999) reports that with the rising costs of professional training and workshops, employers are reluctant to fund continuing education opportunities. These types of indicators may suggest that training in alaryngeal speech is lacking.

For those speech therapists who work with laryngectomees, certain roles have been identified. The speech-language pathologists= role in working with laryngectomees is that of a teacher, clinician, advisor, and counselor (Van Riper, 1978). Salmon (1986) offers several role-based areas to be covered with the laryngectomee based on a descriptive survey issued to laryngectomees and their spouses. Salmon=s study involved 100 questionnaires, of which 66 were completed and returned. Respondents were from 17 states and included 53 spouses and 13 laryngectomees. Based on the results of her survey, Salmon created a checklist for the early pre-operative and post-operative phases of speech therapy. The checklist was derived from key areas of concern from the survey respondents. On a pre-operative level, patient inquiry and education were a major focus. Salmon suggests that what the patient and spouse already know about the surgical procedure will determine what additional information is provided. In this stage of speech therapy, Salmon suggests that the patient and spouse understand: 1) anatomical changes, 2) the post-operative conditions the patient will experience, 3) that there are alternative methods for communication and, 4) that the speech pathologist will return after surgery to begin treatment. In the next several post-operative visits, the speech therapist disseminates educational literature and educational videos. The speech therapist provides information regarding to stoma products, emergency neck-breather bracelets, and provides instruction with the artificial larynx. Visits with another rehabilitated laryngectomee are also arranged during the post-operative stage.

Importantly, the role of the speech therapist also includes the selection of the artificial larynx. Salmon (1999a) suggests that the speech therapist present the advantages and disadvantages of the various models and the features that are unique to a given brand. In her discussion of the selection process, Salmon explains that device placement on the neck, sound activation, and listening to the sound quality are determining factors in the selection process. Because each patient is different in tissue density, size, shape, and resonating cavities, the sound production varies from patient to patient. Because of this point, Salmon explains that no one can predict with any accuracy which specific device will be best suited for a given patient. Lerman (1991) explains that the role of the speech therapist should be to orient the patient to all available devices. With this, Lerman states that the speech therapist should be knowledgeable and practiced in the use of the various devices so that he or she can adequately demonstrate the devices and their features.

Both Lerman (1991) and Salmon (1999b) explain the role of the speech therapist in determining optimal device coupling and resonation. When the artificial larynx is positioned properly on the neck, greater resonance and sound production is achieved. Lerman (1991) and Salmon (1978, 1999a) explain that finding the optimal neck placement should be accomplished on an experimental level. Salmon (1999a) suggests that the speech therapist can first feel the patient=s neck to locate a soft, pliable spot that can accommodate the vibrating head of the device. The areas around this spot are then used to experiment with device placement. Lerman recommends having the patient produce the neutral vowel while placing the artificial larynx in various locations until the clearest tone quality is observed. Other areas that need to be addressed by the speech therapist include on-off activation of the device, placement pressure of the vibrating head upon the neck, and articulation strategies (Lerman; Salmon, 1999a).

Studies Surrounding Artificial Larynx Devices

Historically, studies that have focused their attention on artificial larynx devices, have done so on a perceptual, intelligibility or acoustical level. That is to say, how artificial larynx users are perceived by listeners; how well users are understood by listeners; and what acoustical characteristics a given device manifests.

In his discussion at the American Speech and Hearing Association=s 1967 convention, Duguay reported on seven different speech devices including neck, intraoral and pneumatic types. Duguay=s test devices included the Western Electric #5 with a flat vibrating head, Western Electric #5 with a tapered head, Aurex, Cooper-Rand, Western Electric pneumatic device, the DSP8, and the Tait Oral Vibrator. Phonetically balanced word lists were used as the stimulus to be judged by naive and sophisticated listeners. Naive listeners were those individuals who had no listening experience with artificial larynx speech. Sophisticated listeners included speech therapists and individuals who had experience listening to artificial larynx users. While it is unknown how many subjects the study included, Duguay found no statistical difference in intelligibility between the devices. A noticeable difference, however, was reported in perceived quality between the different devices. That is to say, various devices offered the same ability to be understood, however they differed in their acceptability to be heard by the listeners.

In 1976, Goldstein and Rothman studied several facets of artificial larynx speech. The first facet focused on the artificial larynx and relationships to frequency, speech rate, and intensity. Using 15 artificial larynx speakers, subjects were instructed to read eight standardized sentences prepared by the Central Institute for the Deaf. Sentences were audio recorded and rated in proficiency by six Aexperienced≅ speech pathologists on a likert scale. From this rating system, subjects were collapsed into either a poor or good speaker group. Subjects from the two groups were then analyzed in terms of speech rate, frequency, and intensity. The artificial larynx devices that were used in the study included the Western Electric and the Aurex Neovox. While these devices are no longer manufactured, the researchers found that speakers in the good proficiency group had greater intensity, more frequency variation and slower speech. Statistically, using the Spearman Rank Correlation Coefficients Test, the researchers found a high correlation between intensity, speaking rate and ratings of speech proficiency. To study measurements of frequency range, subjects were instructed to read the 12-word sentence, AHow do you feel about changing the time when we begin to work.≅ Measurements of frequency were obtained using a Honeywell 1508A Visicorder which is a paper read-out oscillograph. Speakers in the poor group were able to vary pitch 11.10 Hz while speakers in the good speakers group were able to vary their pitch 16.10 Hz. Using the Mann-

Whitney U nonparametric test, the researchers determined that the two groups were significantly different.

The second aspect of Goldstein and Rothman=s (1976) research investigated spectrographic articulation patterns of both groups of poor and good artificial larynx speakers. Devices used for this facet of the study included the Western Electric and the Aurex. Using a Spectrograph machine which provides a graphic display of a given signal, spectrograms were made of the following three sentences: I don=t want to go to the movies tonight; Do you think that she should stay out so late; This suit needs to go to the cleaners. Spectrograms were then analyzed and the data showed that good speakers demonstrated greater duration of certain phonological patterns. These included the phonemes, /d/, /t/, and /s/. Speakers in the good group were able to differentiate and use the device systematically when producing voiced and unvoiced consonants. Cognates are sounds that are differentiated by their voiced or voiceless production. The good artificial larynx speakers found in Goldstein and Rothman=s study were able to precisely turn on and off the artificial larynx to highlight these sound variations.

Some authors have suggested that artificial larynx speech lacks in certain frequency spectrum. Frequency spectrum refers to the frequencies generated from a given device. Qi and Weinberg (1991) studied the Servox Inton artificial larynx and determined that the device was significantly deficient in low frequency energy. For part of their study, they analyzed a single Servox in a free, uncoupled field with the test microphone placed about 10 cm from the vibrating surface of the larynx. Results of their data suggested that the Servox device had a low energy deficit below 400-500 Hertz. For the next portion of their exploratory and perceptual study, the researchers used five male laryngectomees and 10 normal speakers for speech samples. Each subject produced randomized selections of ten vowels while being recorded using a SONY TC-RX400 recorder and an ASTATIC TM-80 microphone. The speech samples involved the production of vowels placed in the sentence frame, AI will say h_d.≅ Samples were then digitally recorded and low frequency enhanced. Overall the filtered samples were preferred by graduate speech and hearing students. While the authors stated that all five alaryngeal speakers had used a Servox electronic larynx as their primary method of oral communication for more than one year, they did not comment on the condition, age, or battery status of the devices used by the laryngectomee sample. According to Lerman (1991) several factors, including battery condition, can influence the function of an artificial larynx.

Epsy-Wilson, Chari, MacAuslan, Huang and Walsh, (1998) investigated filtering to remove extraneous noise from the Servox artificial larynx. Speech samples were obtained from four subjects; two laryngectomees and two normal speakers. The laryngectomized subjects included a 57 year old male and a 70 year old female. The normal speakers included a 47 year old male and a 38 year old female. Both groups were instructed to read portions of the standardized Rainbow Passage and the Modified Rhyme Test. Samples were digitally recorded and altered using a filter that mimicked a telephone circuit. A preference rating system using college students at the Boston University was used to study voice quality and intelligibility with and without the filtering. While intelligibility of both groups was not improved by the filtering, perceptual preferences leaned favorably towards the filtered speech. The combined preference score of the filtered laryngectomized sample was 60.2%; the preference score for the non filtered sample was 7.7%. From this information, the authors envision a stand alone device that can be used to enhance artificial larynx speech for improved use with telephones. Like Qi and Weinberg=s (1991) study, no effort to control the condition of the single Servox was implemented. The age, condition, and battery status of the device was also not addressed.

Watterson, Cox, and McFarlane (1998) studied vowel perception and sentence intelligibility using the Servox, AT&T, Neovox, and Jedcom neck type devices. Subjects for the study were eight male laryngectomees ranging between 55 to 97 years of age. Each subject was instructed to produce four isolated vowels and three standardized sentences using each of the artificial larynx devices. Samples were recorded and played back to a panel of seven Aexperienced≅ listeners in alaryngeal speech. Prior to recording, each subject was allowed to practice with each of the devices. The subjects were allowed to change the pitch and volume of each device to suit personal preference. The results of the research showed the /u/ vowel was least identified by the listeners and the /a/ vowel was most identified. In terms of sentence intelligibility, there were no statistical differences in sentences produced among the Servox, AT&T, and Neovox devices. The Jedcom, on the other hand, had a significantly lower intelligibility score. While the authors state that the devices were recently purchased and had never been used, it is uncertain what their condition and battery status entailed. Of interest is the fact that only the Servox is manufactured at this time. The other devices were discontinued prior to 1995 (Communicative Medical, 1995).

Grant (1997) studied the Servox and TruTone artificial larynges and provided an in-depth spectral analysis of these devices. Samples included air-conduction measurements of new devices and those of laryngectomee subjects. The subjects included a 65 year old female and a 56 year old male who were long-time users of both the Servox and TruTone artificial larynges. Complex measurement and analysis of spectral tilt, harmonic intensity, and harmonic-to-noise were obtained for each device and compared to each other, and then to normal speech characteristics. Grant concluded that both relative and harmonic intensity in the TruTone artificial larynx were factors that approximated normal speech. In terms of frequency, Grant determined that fundamental pitch range of the Servox could be statically adjusted between 48.5 - 183.5 Hz. The TruTone had a dynamic pitch range between 48.2 - 206.2 Hz. Data indicate that the TruTone had greater frequency range and harmonic intensity compared to the Servox. Grant=s findings suggest that the TruTone device approximate normal speech more so than the Servox device.

Characteristics of Artificial Larynx Devices

Quality

Perhaps one of the only, non-manufacturer references to quality and reliability is provided by Barney (1958) when considering the ideal device. Barney also lists a number of attributes which included:

1. Reliable; with trouble free operation for long periods of time
2. Output speech quality and pitch inflection like that of normal speech.
3. Unobtrusive; without visible wires, tubes, or other appurtenances, and small in size.
4. Output speech volume equal to that of a normal speaker

5. Hygienically acceptable to the user.

6. Inexpensive price and low operating cost.

As a historical note, the reader will recall that Bell Telephone Laboratories (AT&T, 1998) was instrumental in the development of the Western Electric Model 5 artificial larynx. Barney (1958), who worked for Bell Laboratories, attempted to incorporate these attributes in the Western Electric device (Western Electric, 1964).

Reliability refers to the extent that an instrument provides the same results with repeated administration (Singh & Kent, 2000). When applied to an artificial larynx, reliability can then be viewed in terms of the consistency of the controls, pitch, volume, and sound quality. Given the important role that the artificial larynx plays, little or no investigative work has been conducted in the area of artificial larynx reliability. When reviewing the product manuals that accompany artificial larynx devices (Romet, 1999; Siemens, 1999a; Griffin Laboratories,1999), some common cautions are provided. These generally include the avoidance of exposure to shock, moisture, and heat. This same literature offers certain precautions that pertain to the batteries that power such devices. These include short-circuiting, over-charging, and charging in the reverse position. In 1999, Servox (Siemens,1999b) introduced a new nickel-metal-hydride battery instead of the standard nickel-cadmium battery. These batteries have the advantage of higher capacity, longer talk time, and no short charge memory (Siemens 1999b).

Several factors can have a negative affect on an artificial larynx device. In his discussion of trouble shooting the artificial larynx, Lerman (1991) states:

> Do not abuse the device by banging or dropping it. When not in use, make sure the device is kept in a pocket or other receptacle where it will not be damaged.

> Do not leave an electronic device exposed to excessive moisture. None of these devices is guaranteed for moisture damage. Make sure that the device is turned off when not in use. Check the device each morning before using it to note any changes in its functioning. Like all mechanical devices, the artificial larynx is subject to malfunction and breakdown. This will cause concern on the part of the laryngectomee and family; however, a great deal of this concern can be avoided when both the patient and the family are well acquainted with the device and how it functions. A variety of mechanical difficulties can occur. (p. 43)

Characteristics and Ergonomics

While little has been written on the characteristics and physical properties of the artificial larynx, one way to view this area is through that of ergonomics. According to Osborne (1982), the term, ergonomics, has Greek derivation: ergon-- work; nomos-- natural laws. Specifically, the area of ergonomics seeks to maximize a given tool, device or environment to the functions and limitations of a person. Otherwise known as Ahuman factors≅ (Sanders & McCormick, 1987), ergonomics addresses the relationship between people and machines and includes such things as controls, displays, shapes, movements, and so on (Osborne). Such a relationship is referred to as the Auser-machine interface≅ (Galer, 1987) or the Aman-machine system≅ (Osborne). Galer suggests that the fit between a person and a machine can be viewed in terms of physical, psychological, and biological characteristics. On a physical level, for example, the study of ergonomics may study the size, shape, or strength of the human body. On a psychological level, reactions times to a given stimulus may be studied. Biologically, the way a muscle fatigues may be of interest. As a consequence of not using ergonomics Galer explains that the user can experience physical harm or extreme frustration when trying to compensate for a poor design. The user may experience stress and strain and errors may be increased. Additionally, the user may develop feelings of dissatisfaction and discomfort. The general components of a neck-type artificial larynx are typically contained in a tubular apparatus. These include the: 1) battery and its compartment, 2) timer circuit/pitch control, 3) on/off switch, 4) volume control, 5) electromagnetic plunger, and 6) hard membrane/drum. The entire device is held to the neck for signal transfer. Osborne (1982) explains that some hand held devices require that the wrist be bent. Under continuous operation such a position can cause muscle fatigue and loss of efficiency. The device can be dropped and suffer damage. Significantly, Lerman (1991) warns that artificial larynx devices should not be bumped or dropped as damage can occur.

In regards to controls and their functions Galer (1987) claims that large amounts of force are only required for the following categories: 1) emergency 2) occasional use and 3) hand tools for maintenance work. Conversely, other control functions require a small amount of force. Osborne (1982) explains that thumb controlled buttons should be 2 cm in diameter and finger operated buttons should have a minimum diameter of 1.5 cm. The amount of resistance of a button is dependent upon function. Moore (1975) indicates that push buttons should have a resistance of 283-2272 grams if the thumb is used and 140-560 grams if other fingers are used. Importantly, too little activation pressure can result in false activation. Sanders and McCormick (1987) describe backlash as the amount of dead space in a control before it is activated. Backlash can be likened to a joystick with a loosely fitting tube over the actual stick. The controls become less responsive and sloppy giving rise to system errors (Sanders & McCormick).

Most artificial larynx devices utilize a knob or dial to control volume (Bivona, 1997; Romet, 1998; Siemens, 1999a; Griffin Labs, 1999). The knobs and dials on artificial larynx devices are considered low friction because they require little force to move. Osborne (1982) indicates that dials should not be excessively small to prevent them from being gripped and turned easily. No information has been found relating user attitudes and whether or not a given artificial larynx is comfortable to use.

Acoustic Properties

Goldstein and Rothman (1976) showed that several aspects of the artificial larynx and its user can impact the proficiency of speech. When looking at the acoustical properties of frequency and intensity, the researchers note a statistical significance that correlated intensity to speech proficiency. Using 15 artificial larynx speakers, subjects were instructed to read eight standardized sentences prepared by the Central Institute for the Deaf. Sentences were audio recorded and rated in proficiency by six Aexperienced≅ speech pathologists on a likert scale. From this rating system, subjects were collapsed into either a poor or good speaker group. Subjects from the two groups were then analyzed in terms of speech rate, frequency, and intensity. The artificial larynx devices that were used in the study included the Western Electric and the Aurex Neovox. While these devices are no longer manufactured, the researchers found that speakers in the good proficiency group had greater intensity, more frequency variation and slower speech. Statistically, using the Spearman Rank Correlation Coefficients Test, the researchers found a high correlation between intensity, speaking rate and ratings of speech proficiency. To study measurements of frequency range, subjects were instructed to read the 12-word sentence, AHow do you feel about changing the time when we begin to work.≅ Measurements of frequency were obtained using a Honeywell 1508A Visicorder which is a paper read-out oscillograph. Speakers in the poor group were able to vary pitch 11.10 Hz while speakers in the good speakers group were able to vary their pitch 16.10 Hz. Using the Mann-Whitney U nonparametric test, the researchers determined that the two groups were significantly different. When compared to intensity, frequency to a much lesser degree was associated to speech proficiency. In his discussion of ideal attributes of an artificial larynx, Barney (1959) suggests that intensity and pitch inflection of an artificial larynx should approximate that of a normal speaker. Rogers (1994) notes that even the maximum volume levels on a given artificial larynx can be too low depending on the needs of the speaker. On an external level, factors including speaker role, listener demands, and room acoustics can influence loudness of a device. Lerman (1991) contends that battery problems can be responsible for problems that can ultimately affect device pitch and volume. Compared one to another, little information has addressed user attitudes of loudness and frequency capabilities of artificial larynx devices.

Chapter Summary

The normal voice is the result of the larynx. Sounds generated by the larynx move up through the vocal tract and transform into words by way of articulatory movements. Laryngeal cancer is typically the result of tobacco and alcohol abuse and is considered a head and neck cancer. Most laryngeal cancers are squamous cell and are tumors that grow to invade surrounding and distant tissues and organs.

When ablative surgery necessitates the removal of the larynx, the laryngectomee will require a new vocal system. For many people, the artificial larynx will provide the voicing necessary to carry-on oral communication.

The foundation of the artificial larynx has its beginning in the middle 19th century. With the ripe understanding of electricity and the development of neck-type devices, artificial larynges have progressed to their current position in the market place.

Beyond the history of artificial larynx devices, studies have tended to address intelligibility and perceptual issues. Importantly, there remains a gap in the literature that addresses the reliability of these machines according to the people who are closest to them: laryngectomees and speech therapists. As a tool that provides an essential communicative function, their performance and failure is of critical concern. As an electro-mechanical piece of equipment, the artificial larynx is prone to a problems.

While the selection of artificial larynx devices occur with and without the assistance of speech-language pathologists, data collected from both users and speech pathologists would be useful. By querying laryngectomees and speech pathologists, valuable information regarding reliability and selection can be obtained.