

SIG 3**Review Article**

Wound Healing and Special Considerations for the Professional and Performing Voice

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https://doi.org/10.1044/2023_PERSP-23-00083**ABSTRACT**

Purpose: The purpose of this article is to review the wound healing process of the vocal fold following phonomicrosurgery to remove benign vocal fold lesions in professional voice users. Understanding this process and the risk of developing scar tissue at the injury site is important for treatment of these individuals. This review also highlights special considerations during the postinjury rehabilitation period and the unique vocal loading tasks and needs of performing voice users. The goal of this article is to provide clinical tools for wound healing education to nonvoice-specialized speech-language pathologists to inform their rehabilitation of the professional and performing voice user.

Conclusions: Implications intrinsic to vocal fold physiology and the stages of wound healing necessitate the avoidance of scar tissue with a rehabilitation plan tailored to the unique vocal loading demands of professional and performing voice users. There is a need to develop specific rehabilitation protocols that are genre-specific to aid in the individual treatment of the elite vocal athlete.

Our current understanding of the vocal fold wound healing process following surgical treatment for benign vocal fold lesions is primarily based on animal studies (Branski et al., 2005; Rousseau et al., 2003; Rousseau, Hirano, et al., 2004; Rousseau, Sohn, et al., 2004) and studies involving normal voice use in humans (Coombs et al., 2013; Divakaran et al., 2015; White & Carding, 2022). However, there is still limited research specifically addressing the unique challenges faced by professional voice users and how their increased vocal load may affect the healing process. Increased vocal load refers to phonation that is above normal levels of frequency, duration, or intensity (Solomon, 2008). By gaining a better understanding of the unique challenges faced by professional voice users, clinicians can develop more effective treatment approaches and guidelines to optimize vocal health and recovery for these individuals.

According to the American Speech-Language-Hearing Association (ASHA), the graduate student clinician's

education must include the demonstration of competencies on the evaluation and treatment of voice disorders. In 2003, ASHA's Special Interest Group 3 developed a sample curriculum for a graduate-level voice disorders course in response to the joint statement issued by the Council on Academic Accreditation in Audiology and Speech-Language Pathology and the Council for Clinical Certification in Audiology and Speech-Language Pathology. The syllabus includes topics on general scientific principles of voice production, such as anatomy and physiology, histology, and the biomechanics of voice (ASHA Special Interest Division 3, 2003). The developers of the sample curriculum also advised that graduate students demonstrate their knowledge of the various structural and functional changes that can lead to voice disorders. Many textbooks used for these courses on voice disorders include information on these tenets of voice production and discuss their implications and special considerations for the performing voice user (Boone et al., 2020; Stemple et al., 2020). During a typical voice disorders course, some of the more complex scientific topics that form the basis for our rationale for various diagnostic and treatment approaches are often omitted from the course. For example, a typical

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voice disorders course may cover the importance of avoiding scar tissue if a patient undergoes phonomicrosurgery; however, the physiological process of wound healing at the incision site is typically not discussed. An understanding of this process will aid the clinician in both educating their patients and planning for their voice therapy. In 2006, Branski et al. published a review of the vocal fold wound healing process to help clinicians fill in these knowledge gaps with basic and translational science.

Predisposing Factors in Professional Voice Users

Performing voice users are more susceptible to phonotraumatic lesions due to the higher impact stress and vibratory dosage than nonoccupational voice users (Toles, Ortiz, et al., 2021). Speech-language pathologists who assess and treat these individuals must recognize their more significant professional stakes and occupational voice requirements. Clinicians should be able to educate these patients on the vocal fold wound healing process as it may directly affect their vocal health and consequently many aspects of their life such as emotional health and monetary impact from taking time off for recovery (Etter et al., 2013). A patient who understands the rationale for the recommendations is also more likely to adhere to these recommendations (Martin et al., 2005). Additionally, the therapeutic component for various performing voices must be individually tailored based on genre and performing requirements. For example, an opera singer needs to sing 3-hr performances twice per week at a typical 100 dB SPL throughout a sung range of 2.5 octaves compared to a musical theater singer whose role may include a reduced frequency and intensity range but needs to sing 2-hr performances 8 times per week (Björkner, 2008). The purpose of this review is to serve as a guide for clinicians by applying the existing knowledge on wound healing to the recovery process for performers after undergoing phonomicrosurgery for benign vocal fold lesions.

Brief Overview of Vocal Fold Physiology and Injury

Histologically, the vocal folds are comprised of different layers of tissue. From outermost to innermost, they are the epithelium, lamina propria, and striated muscle. The epithelium is composed of squamous epithelial cells, which are covered by a mucinous layer. The mucinous layer is responsible for protecting the epithelium of the vocal folds and can be impacted by dehydration. It also contributes to the vibratory characteristics and lubricating properties of the vocal folds (Gray, 2000).

Underneath the squamous epithelium lies the basement membrane zone (BMZ), which connects the epithelium

to the superficial layer of the lamina propria (SLLP). The BMZ is structured by both protein and nonprotein fibers. The BMZ allows the epithelium to connect with the SLLP through anchoring fibers made of collagen. These anchoring fibers are essential during stress, such as voicing. The BMZ, with the epithelium and the SLLP, forms the vocal fold cover (M. Hirano, 1981). According to the Cover-Body Theory, during phonation, the vocal fold cover layer vibrates as a result of the aerodynamic forces exerted by the passing airflow from the lungs. As the cover layer oscillates, it transfers these vibrations to the body, creating a wavelike motion that generates sound. The body consists of the intermediate and deep layers of the lamina propria with the vocalis muscle. The Cover-Body Theory emphasizes the importance of the layered structure of the vocal folds and highlights the distinct roles of these layers in voice production. This model has provided valuable insights into the understanding and treatment of various vocal pathologies, as well as the development of vocal techniques and therapies (M. Hirano & Kakita, 1985).

The entire lamina propria is composed of three layers: superficial (SLLP), intermediate (ILLP), and deep (DLLP). These layers are distinguishable by the concentration of elastin and/or collagen fibers. The SLLP is composed of loose collagenous fibers, the ILLP of more elastin fibers, and the DLLP of dense collagenous fibers. The intermediate and deep layers comprise the vocal ligament. The combination of collagen and elastin fibers provide the vocal folds with a structure that is both strong, allowing it to withstand mechanical stress, and elastic, allowing its shape to deform and reform. The lamina propria can also be categorized by its cellular and noncellular material (extracellular matrix or ECM; Gray, 1991; Titze, 1994; Tucker, 1987).

The ECM contains fibroblasts, myofibroblasts, and macrophages, which are used in the vocal fold wound healing process. Macrophages respond to the inflammatory stage of wound healing. Myofibroblasts and fibroblasts assist in repair, and fibroblasts help to maintain the lamina propria. These cells repair and construct the ECM following tissue injury. They have been found to be constantly present in the vocal fold tissue, which indicates that there is some consistent level of injury in the vocal fold tissue, with the highest concentration in the SLLP (Colton et al., 2011). If the injury exceeds this consistently present level of injury, due to increased vocal loading, a pathology may occur. The most common area for injury and pathology is within the SLLP following phonotrauma or from a surgical incision following phonomicrosurgery (Jiang et al., 2000; Noordzij & Ossoff, 2006).

Stages of Vocal Fold Wound Healing

There is a constant injury and repair cycle present in the vocal folds. The wound healing process of the vocal

folds can be divided into four phases: inflammation, ECM deposition, epithelialization, and tissue remodeling. Inflammation is the body's initial response to injury (Trowbridge & Emling, 1997). In this stage, a blood clot stops the bleeding from the injured vessels and releases macrophages and other inflammatory cells into the injury site. The duration of the inflammatory stage is typically 1–3 days (Hackam & Ford, 2002). Once inflammation begins to resolve, the ECM deposition phase begins when fibroblasts enter the injury site and release new ECM material about 48–72 hr postinjury. Myofibroblasts also enter the wound to contract and assist with scar formation shortly thereafter (Gabbiani, 2003). During the epithelialization stage, an impermeable seal begins to develop at the injury site 24–48 hr after injury. The final phase, tissue remodeling, can last up to 12 months following an injury and may begin as an early scar at 1–3 months and form a mature scar soon thereafter.

The BMZ has been shown to repair microscopic injury within a relatively short timeframe of 36–48 hr (Gray, 1991). The ability of the BMZ to repair microscopic injuries within a short timeframe is crucial for maintaining vocal fold health, preventing scar formation, and preserving the structural and functional integrity of the vocal folds. Postsurgical rehabilitation aims to optimize recovery by considering these stages of wound healing. It involves determining appropriate durations for voice rest and voice use based on the specific phase of healing to support effective tissue repair and minimize complications. Rehabilitation protocols may be individualized based on the nature and extent of the vocal fold injury, as well as the needs of the patient. It is important to note that the healing process may vary for different individuals and types of vocal fold injuries.

Voice Rest

It is important to remember that the four stages of wound healing are constant processes in the vocal folds to repair injury from normal/everyday use or otherwise. Currently, we know that voice rest is a necessary component to allow for the healing and re-epithelialization of vocal fold tissue following surgery or injury (Coombs et al., 2013; Kaneko & Hirano, 2017; King et al., 2021; Koufman & Blalock, 1989; Martins et al., 2016; Rousseau et al., 2011). Based on the animal studies, current clinical recommendations include at least 3 days of complete voice rest to allow the inflammation to resolve (Mitchell et al., 2014). There is a risk of scarring at the surgical site following this initial wound healing phase. Scarring replaces healthy tissue with fibrous tissue and is detrimental to mucosal pliability. Stroboscopic examination will indicate a reduced mucosal wave and possible disruption of other vibratory features, such as periodicity (Benninger et al.,

1996). This can lead to a permanent negative change in vocal quality, and its development should be avoided (Hansen & Thibeault, 2006; S. Hirano, 2005).

Scar tissue formation in the vocal fold epithelium may be abated or reduced with therapeutic use of the voice following resolution of the inflammation phase while on complete voice rest (Kaneko & Hirano, 2017). However, it is essential to identify the adequate dosage of voice use for each individual as there is a negative impact of too much vibratory dosage as well as too much vocal rest (Johnson & Sandage, 2021; Rousseau et al., 2003; Rousseau, Hirano, et al., 2004; Rousseau, Sohn, et al., 2004). Two types of voice rest have been examined singularly and in combination for postsurgical rehabilitation. Complete voice rest is defined as no voicing or the absence of vocal fold contact, whereas the definition of relative voice rest has been shown to differ between clinicians to include varying durations of controlled voice use (Joshi & Johns, 2018; Whitting et al., 2018; Rihkanen & Geneid, 2019). Recent studies comparing the two types of voice rest do not show a difference in outcomes (Coombs et al., 2013; Dhaliwal et al., 2020; Divakaran et al., 2015; Koufman & Blalock, 1989; White & Carding, 2022), but a recent meta-analysis by Chi et al. in 2023 showed that a short duration of voice rest (less than 7 days) resulted in better quality of life.

Current literature suggests that inflammatory markers may be reduced following high vocal loading tasks using therapeutic tasks such as those requiring a resonant voice quality versus voice rest alone (Verdolini Abbott et al., 2012). A specific timeline for the reduction in inflammation was determined by the analysis of inflammatory biomarkers in secretions. Further investigation is necessary to examine a potential prophylactic voice rest timeline to reduce inflammation and support the innate wound healing phases.

Professional Voice Users

A person's voice use and overall vocal load vary over the course of a day, depending on their occupation or social/familial responsibilities. Occupations dependent on the voice can be as varied as telemarketers, teachers, broadcasters, fitness instructors, or singers. The increase in vocal load for professional voice users makes them particularly susceptible to vocal fold injury due to the increased mechanical stress during occupational voice use. This makes the pervasive wound healing process in the vocal folds particularly beneficial. During phonation, the vocal folds typically collide between 100 and 230 times per second depending on the pitch being produced. This collision rate, known as the fundamental frequency, is influenced by factors such as the mass and length of the vocal folds (Boone et al., 2020). Biomechanical stress in teachers was examined by measuring the repetitive collision forces of

the vocal fold tissue (in the classroom) and recovery from that stress (at home/not in the classroom). It was found that teachers vibrate their vocal folds approximately twice as much when they teach as opposed to when they do not teach (Titze et al., 2007). This finding suggests that teachers are more susceptible to vocal fold injury due to their occupational vocal demands. These vocal load requirements need to be addressed during postinjury voice rehabilitation. As such, it is important to investigate the dosage of voice rest during postsurgical rehabilitation of professional voice users, particularly singers, because of (a) the potential negative financial effects of work loss, (b) their highly specialized vocal loads when they do return to work, and (c) the importance of a healthy vocal technique following, and during, rehabilitation (Bhattacharyya, 2014; Gaskill & Weems, 2009; Martins et al., 2016; Williams, 2003). Interestingly, professional singers have been shown to use their voices in speech for significantly greater duration than in singing when they are injured (Toles, Roy, et al., 2021). This may be due to the separation of their perceived high demands and heightened awareness during singing as compared to speech. This is an additional consideration for clinicians as they create highly individualized treatment plans for the professional singer.

Performing Voice: Clinical Considerations

In 2005, ASHA's Ad Hoc Joint Committee with the National Association of Teachers of Singing and the Voice and Speech Trainers Association published a technical report, "The Role of the Speech-Language Pathologist, the Teacher of Singing, and the Speaking Voice Trainer in Voice Habilitation" to address the augmented skill set required to treat performing voice users with voice disorders. Many voice clinics treat professional voice users as part of their normal clinic schedule, which includes singers from various musical genres; however, this skill set is arguably necessary for the general SLP, who is the sole resource for voice rehabilitation in their area and who may, therefore, find themselves providing treatment to elite performing voice users. This is important as professional singers have been shown to have an increased risk of voice disorders associated with high vocal load and phonotrauma (Kwok & Eslick, 2019; Phyland et al., 2013). Additionally, regardless of genre, singers have been shown to report and seek treatment for self-perceived dysphonia (Pestana et al., 2017). Professional singers have also shown a distinction between the perceived higher demands of vocal loading for their voice use in singing versus speaking, as they used their speaking voice for a significantly longer duration than their singing voice when injured (Toles, Roy, et al., 2021). This may be due to their heightened auditory and kinesthetic awareness skills gained as part of their vocal training, with which they may be more likely to perceive discrete changes in their vocal quality.

Phonotraumatic lesions may be treated using voice therapy alone as a conservative approach or pre-/postphonomicrosurgery to remove the lesion. The vocal rehabilitation component needs to be specific and rigorous enough to prepare them to return to their heavy occupational vocal load following surgery (Zeitels et al., 2002). The singer may feel pressure to return to their rehearsal and performance schedule earlier than advised to avoid the loss of present (and future) income. Considering each singer's individual training and professional obligations, a rehabilitation plan should be developed in collaboration with the phonosurgeon and based on the principles of vocal fold wound healing in order to minimize scarring at the incision site while also increasing (a) vocal load over time and (b) the ability to endure high biomechanical and bioenergetic forces for prolonged periods, as is the case for many musical genres (Sandage & Smith, 2017).

Future Directions

The initial, 7-day voice rest component has previously been studied; however, the actual events and timeline following the first postoperative week should be investigated further to determine appropriate protocols. Based on current evidence, we know that 3 days of complete voice rest is beneficial, followed by a short duration of controlled voice use. However, in the absence of research on the ideal duration and components of the latter, an evidence-based protocol cannot be developed. For professional voice users, particularly for the performer, additional factors such as warm-ups and the process of increasing vocal load to full performance capacity in terms of frequency, duration, and intensity need to be examined. See the Appendix for additional considerations to be made during a clinical assessment to inform the individualized treatment plan and therapy goals for the professional singer. Each vocal athlete requires an individualized plan based on their genre, vocal load, rehearsal, and performance schedule. Future studies should examine these variables to allow for improved clinical outcomes and a lifetime of elite voice use for this specific population.

Data Availability Statement

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

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Appendix

Case History: Additional Considerations for the Performing Voice User

Personal Audio Equipment Use		
Microphone: Yes/No	Type:	Location:
Monitor: Yes/No	Type:	Location:
Typical Venue		
Describe typical venue:		
Size of hall/room:		
Size of stage/performance space:		
Typical type of attendee (silent vs. participatory):		
Additional Performance Requirements		
Instrument(s) played by performer:		
If used, how are these instruments amplified and monitored:		
Dance requirements and level of physical demand:		
Any unique vocal demands (e.g., screaming):		
Presence and size of other singers/ensemble(s):		
Presence and size of supporting instrumentation (e.g., orchestra, band, etc.):		
How are those additional instruments amplified and monitored:		
Personal Supports or Barriers		
Support System (e.g., Agent, Manager, Other Staff):		
Historical Vocal Training:		
Current Vocal Training:		
Potential Barriers:		
Current Vocal Practices <i>Specific Tasks, Task Duration, Frequency Range, and Intensity Range</i>		
Warm-Up:		
Cool Down:		
Typical Performing Voice Use Requirements:		
Typical Overall Voice Use (include social use and other/additional occupational vocal demands):		