Science for Singers

A SERIES OF VOICE RESEARCH COLUMNS BY INGO R. TITZE, PHD

On the Springiness and Stickiness of Vocal Fold Tissues

In our laboratories at the National Center for Voice and Speech, we have acquired a modern technique for measuring the "stickiness" and "springiness" of human tissues, especially vocal fold tissues. In more precise physical language, "stickiness" is called *viscosity* and "springiness" is called *elasticity*. Small samples of tissue (a few mm^3) are placed between two disks, one of which is stationary and the other rotates back and forth with a small angle, dragging the tissue with it. The viscous drag force is measured and calibrated to yield the elasticity and viscosity of the tissue.

Why are these physical properties of vocal fold tissues important? Because they determine how easy it is for singers to vibrate their vocal folds. Vibration always includes viscous drag. It is impossible for the vocal folds to deform without some portions of tissue being dragged over other portions. The molecules have to slip and slide over each other, often creating more or less entanglement, and hence friction.

We all know that some days our voices are very easy to get going - soft sounds and crescendos are no problem. On other days it's a real chore to get a consistent voice onset. The vocal folds seem to respond only at medium to loud intensity.

Much of this variability in ease of voice onset has to do with the viscoelastic properties of the vocal folds. These properties can vary with exposure to chemicals, humidity, food and drug intake, and respiratory infection. Most of all, it is believed (but not yet proven) that the viscoelastic properties may change with an ever-ongoing state of repair of the vocal folds. This is a bit like roadwork going on on our highways. After so many hours of mechanical stress between the asphalt and the tires of vehicles, the road surface first begins to buckle, then crack, and finally shed off pieces of asphalt; chuckholes develop, and repair is necessary.

We know that skin on our bodies is in a perpetual state of repair. Surface cells die due to exposure, dryness, or mechanical insult. These cells shed off and new cells are formed on the interior part of the skin, known as the basement membrane region. There is therefore a constant rate of birth and death of cells; if something drastic happens, rapid and massive repair is needed in a shorter period of time.

Similarly, if we use our voice's moderately and consistently every day, some amount of regeneration of tissue will take place in our vocal folds all the time. Some collagen or elastin fibers will tear or become disoriented in repeated stretching and collision. Some will detach from the network and offer little structural support. Messengers are sent out from the cells to report on the state of damage and repair begins. New macromolecules are manufactured, put in place, and debris is removed.

Most of the time all of this goes on without our being aware of it. But after a longer practice or performance, the "road damage" may be a bit excessive. Edema is formed (an accumulation of liquid in the repair process) and the voice responds differently. In mechanical terms, the elasticity and viscosity have changed in the repair process. It's a bit like walking or driving over a freshly repaired road that still has hot tar, loose gravel, or wet concrete in various places. The repair process is incomplete and we must tread lightly.

Should we stop phonating altogether? Not necessarily. Just as road workers can deal with a certain amount of traffic while they are working, the cells can function when there is vocal fold movement. Tissue will repair itself while in use, but a reduced mechanical load is desirable.

Along with tissue obtained from human and animal vocal folds, we have been able to test materials that may be candidates for implantation. Hyaluronic acid, for example, a substance harvested from human umbilical cord, has molecules that can absorb large amounts of water; it has been found to be a regulator of viscosity. It exists naturally under the vocal fold skin. Because there is much deformation right under the skin during vibration, it is believed that hyaluronic acid serves as a lubricant. Fat can also serve a similar purpose. It can be grafted or injected under the skin to correct for rigidity in a vocal fold that developed from scarring.

This research into the molecular and mechanical properties of the vocal fold is quite exciting. In time, we might be able to engineer an ideal vocal fold; but, barring that, at least we can get a handle on why there is so much variation in the "stickiness" and "springiness" of the tissues and help singers become more predictive about the changes that are ongoing in their larynxes.

This column originally appeared in the May/June issue 1998 of The Journal of Singing.