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Biofeedback therapy in cardiovascular disease: Rationale and research overview

ABSTRACT

Biofeedback has much therapeutic potential in cardiovascular diseases, since many of these diseases involve dysregulation of the autonomic nervous system. Studies have clearly demonstrated that patients can use biofeedback techniques to regulate the input of the autonomic nervous system to the heart, but the clinical utility of these techniques has not been well explored in systematic trials. Much biofeedback research to date has focused on patients with hypertension, but outcomes have been inconclusive. Preliminary studies suggest that heart rate variability biofeedback may be useful in improving symptoms and quality of life in patients with cardiac disease, and early studies suggest a possible effect of biofeedback on remodeling of the failing heart. Both of these areas require further research, however. Biofeedback is increasingly used as an adjunct to stress management in cardiac rehabilitation programs, providing the impetus for a large-scale, systematic study of self-regulation in cardiac disease.

The potential of biofeedback therapies in cardiovascular disease is only recently beginning to be explored in a systematic way. This article reviews the rationale for the use of biofeedback therapy in cardiovascular disease and briefly surveys research on the usefulness of biofeedback for several specific cardiovascular parameters and conditions.

RECOGNIZING THE POTENTIAL OF BIOFEEDBACK IN CARDIOVASCULAR DISEASE

Biofeedback is part of a group of modalities known as "self-regulation therapies," in which a subject is taught to control the activities of his or her autonomic nervous system. The autonomic nervous system has also been called the "visceral," "involuntary," and "automatic" nervous system, which suggests that the physiologic processes governed by this branch of the nervous system are largely beyond conscious control. Until the 1950s, this was largely believed to be true. Physicians and scientists had been convinced that the functions regulated by the sympathetic and parasympathetic branches of the autonomic nervous system, such as digestion, blood pressure, and body temperature, were not amenable to self-regulation.

During the 1950s, however, it became clear that functions of the autonomic nervous system could be controlled by conscious thought and training. Subjects could be taught to correctly perceive and also to control heart rate, blood pressure, skin temperature, and other seemingly involuntary functions. The field of biofeedback and applied psychophysiology became possible with these discoveries and with the advent of technologies capable of measuring physiologic variables with enough sensitivity to detect small changes.

Key role of sympathetic/parasympathetic balance

In cardiovascular medicine, biofeedback has a great deal of therapeutic potential because many diseases of the heart and vasculature involve inappropriate regulation of the autonomic nervous system.

Under normal conditions, the sympathetic branch of the autonomic nervous system serves to augment cardiac function in times of stress, increasing heart rate, contractility, and blood pressure, as well as favoring clotting processes that would be mainly adaptive during the "fight or flight" response. The parasympathetic branch of the autonomic nervous system plays the opposite role during health, exerting a calming influence on cardiovascular function.

Normal cardiovascular function is regulated by a balance between sympathetic and parasympathetic inputs to the heart and blood vessels. Heart rate, for example, is governed by the parasympathetic nervous system under resting conditions, when the intrinsic firing rate of the sinus node is decreased by vagal

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input. Under stressful conditions, this inhibition is released and sympathetic excitation can increase the heart rate even further. In many pathological cardiac conditions, such as arrhythmias, an imbalance between the two branches of the autonomic nervous system causes at least some of the disease manifestations and often contributes to progression.

Biofeedback as a 'physiologic beta-blocker'

Another good example is heart failure, where overactivation of the sympathetic nervous system results in many of the phenotypic changes in the myocardium and contributes to the downward spiral from compensatory cardiac hypertrophy to end-stage decompensated failure. The role of sympathetic overactivation in heart failure is clearly evident by the success of beta-adrenergic blocking agents in ameliorating symptoms and delaying disease progression. Given the role of autonomic nervous system dysregulation in cardiovascular diseases, biofeedback therapy has the potential to teach patients a skill that may allow them to decrease activation of their autonomic nervous system, theoretically acting as a "physiologic beta-blocker."

An adjunct to stress management

The potential of biofeedback to have an impact in the arena of cardiovascular disease has not been well explored. Clinically, biofeedback is often used in the context of stress management programs, but biofeedback is not synonymous with stress management. Stress management programs most commonly involve some type of relaxation training and perhaps cognitive behavioral therapy. Biofeedback can be used to augment relaxation, helping the subject to be more aware of physiologic responses and thus be better able to elicit the relaxation response. Biofeedback can also be used to train subjects to control particular physiologic responses that contribute to symptoms or to disease progression. In cardiovascular disease, although stress management is frequently a component of cardiac rehabilitation programs, the question of whether stress management is more effective with or without biofeedback has not been systematically investigated.

PIONEERING STUDIES OF BIOFEEDBACK IN CARDIOVASCULAR DISEASE

Some of the earliest studies of physiologic regulation using biofeedback were attempted in patients with cardiovascular abnormalities. In 1971, Weiss and Engel reported success in using operant conditioning of heart rate in eight patients with premature ventricular contractions.[1] All eight patients were able to achieve some degree of control, and five of the patients were able to decrease the frequency of premature beats, demonstrating increased success over a 21-month follow-up period. Interestingly, use of pharmacologic agents to understand the mechanisms of control suggested that one patient was able to decrease sympathetic control of his heart rate while another increased the parasympathetic influence.

Several years later, Pickering and Gorham reported their work with a single subject, a 31-year-old woman who had a ventricular parasystolic rhythm.[2] Using a biofeedback technique, they were able to teach the woman to voluntarily control her heart rate, demonstrating that she could both increase and decrease the rate, avoiding the ranges in which the arrhythmia occurred. In the same year, Benson et al demonstrated that they could teach patients the relaxation response and decrease the incidence of premature ventricular contractions.[3] Using Holter monitors for validation, these investigators showed that 4 weeks of relaxation training resulted in 8 of 11 patients being able to control their heart rates sufficiently to have therapeutic impact.

These pioneering studies were very early in the development of the field of biofeedback, but they showed what has been clearly established since—that the input of the autonomic nervous system to the heart can be regulated by biofeedback techniques.

BIOFEEDBACK STUDIES OF SPECIFIC CARDIOVASCULAR PARAMETERS AND DISEASES

A host of parameters for assessment

Many cardiovascular parameters can be used for biofeedback. Commonly these include heart rate, blood pressure, skin temperature, and, more recently, heart rate variability. In each case, the parameter is measured and displayed for the subject, and the subject is taught to make it change in a positive direction through relaxation, thought patterns, imagery, or some combination of techniques. Many times the display of the physiologic parameter and the demonstration that it can be controlled are quite surprising to the subject and lead to an enhanced desire to participate in the therapy.

Heart rate variability: A focus of recent interest

The newest parameter in use, and one that has gained considerable interest in the field of cardiovascular biofeedback, is heart rate variability.[4] Heart rate variability refers to the variation within the R-R interval of the electrocardiogram during a fixed cycle. It is associated with adaptiveness of the cardiovascular system, and high variability is believed to be a sign of

health. Low variability is associated with a number of disease states. Heart rate variability reflects the balance between sympathetic and parasympathetic input to the heart, and many cardiac disease states have been shown to be associated with low variability. Therapies that increase heart rate variability have been shown to improve prognosis.

On the basis of these observations, heart rate variability biofeedback is used to train patients to increase the variability in their heart rate, using feedback from equipment that records the R-R interval from the electrocardiogram or from blood pulse volume sensors. Patients learn to make the variability greater, primarily by breathing at a resonant frequency, as described by Lehrer et al.[5]

Several preliminary studies have been conducted with heart rate variability in cardiac patients, but much remains to be understood about its use. In 63 patients with established coronary artery disease, Del Pozo et al showed that six biofeedback sessions coupled with daily practice resulted in significantly increased heart rate variability.[6] Similarly, Nolan and colleagues found that five sessions of biofeedback improved symptoms and quality of life in 46 patients with coronary artery disease.[7] In 14 patients with heart failure, Luskin et al demonstrated that eight sessions of heart rate variability biofeedback produced reductions in perceived stress and improved function on the 6-minute walk test.[8]

It remains unclear whether heart rate variability biofeedback has more or less potential than other types of biofeedback in patients with cardiovascular disease, but these preliminary observations suggest that it may be useful in improving symptoms and quality of life.

Biofeedback in hypertension: Despite decades of study, conclusions elusive

Among diseases of the cardiovascular system, biofeedback has been used most frequently in hypertension, where it has been under investigation for more than 30 years, since the early days of biofeedback study.[9] The field of biofeedback in hypertension is fraught with difficulties, rendering conclusions about its efficacy difficult.

Biofeedback has been assessed in many different types of hypertension, often within the same study. Essential hypertension and "white coat" hypertension, now known as excessive cardiovascular reactivity, have been most commonly investigated, but with no apparent consensus. The biofeedback techniques used in these studies have ranged from blood pressure biofeedback to electromyography, finger temperature, and skin conductance. More recently, heart rate variability biofeedback has also been used in this population.

In general, biofeedback has been more successful in the treatment of hypertension when respiratory training has been a component of the biofeedback. McGrady has established that certain types of patients with hypertension fare better with biofeedback than others.[10] These include patients with higher baseline blood pressure, higher heart rate, cool hands, high electromyographic response, and high plasma renin activity—in short, patients who can be seen to have a high degree of sympathetic arousal.

Blood pressure can be lowered by 6 to 10 mm Hg when biofeedback is effective, which is less of an effect than that observed with most drug therapy for hypertension. Biofeedback does have the advantage, however, of improving overall cardiovascular reactivity and giving the patient a greater sense of control over his or her physical well-being, which may prove valuable in the setting of hypertension. Typically, the most effective interventions for hypertension (and perhaps for cardiovascular disease in general) are individualized for the patient and not protocol-driven. Thus, although biofeedback has potential in hypertension, its efficacy is not proven and systematic trials are lacking.

Biofeedback in heart failure: Targeting sympathetic overactivation

In patients with heart failure, the sympathetic nervous system is overactivated, as noted previously. High levels of plasma norepinephrine correlate with worse prognosis. Decreasing activation of the sympathetic nervous system improves both symptoms and prognosis, as demonstrated in patients taking beta-adrenergic blocking agents or those treated with a left ventricular assist device.

Several studies have suggested that biofeedback may be able to provide a similar reduction in sympathetic nervous system activation in patients with heart failure. Moser and colleagues showed that a single session of skin temperature biofeedback plus relaxation training increased cardiac output in patients with heart failure,[11] while studies by Weiner et al,[12] Bernardi et al,[13] and Mangin et al[14] showed that training heart failure patients to breathe more slowly increased their exercise tolerance. Although these studies are preliminary, they support the speculation that if biofeedback can decrease activation of the sympathetic nervous system in patients with heart failure, it may actually cause some degree of remodeling of the failing heart, such as that observed with beta-blockers or left ventricular assist device therapy.

BIOFEEDBACK AND STRESS MANAGEMENT: AN OPPORTUNITY FOR WIDER IMPACT

As mentioned earlier, biofeedback can serve as a component of stress management programs. Biofeedback is often a very effective adjunct to stress management because it teaches the subject to control physiologic reactions that are part of the stress response and gives the subject feedback to suggest that he or she is adequately practicing relaxation. Biofeedback-mediated stress management may actually be the most practical use of biofeedback in the setting of cardiovascular disease because it is easy to practice and can have an effect on large numbers of patients.

Mental stress has been well documented as a significant risk factor for many forms of cardiovascular disease, and stress management programs have been shown to have an impact on disease progression and symptoms. Many studies, including those reported by Sheps et al for the Psychophysiological Investigations of Myocardial Ischemia (PIMI) study,[15] have shown that patients who exhibit ischemia in response to a mental stress test have increased mortality from cardiovascular disease. Jiang and colleagues,[16] among others, have shown that mental stress predicts cardiac events in patients with lower ejection fractions, and Blumenthal et al[17] have repeatedly demonstrated that stress management training reduces the incidence of wall motion abnormalities in patients with cardiovascular disease. Stress management is included in many cardiac rehabilitation programs, and it is likely that routine use of biofeedback as a component of stress management programs would benefit patients with cardiovascular disease, in whom reproducibly decreasing activation of the autonomic nervous system should be helpful.

According to a recent article in the *Heart Advisor*, 84% of physicians believe that stress is a risk for cardiovascular disease but only 35% say they feel knowledgeable about stress and a mere 5% feel that they succeed in helping stressed patients.[18] Anything that could improve these numbers would be beneficial.

CONCLUSIONS

Cardiovascular conditions in which biofeedback has been shown to be helpful include arrhythmias, hypertension, Raynaud phenomenon, ischemia, infarction, and heart failure, but we have barely begun to explore the potential of biofeedback therapy. Given that many cardiovascular diseases involve inappropriate regulation of the autonomic nervous system, instruction in the use of biofeedback to control activation of the sympathetic and parasympathetic nervous systems is likely to be useful in cardiac patients. Systematic trials are needed.

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