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Review

Meditation: Should a cardiologist care?

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ABSTRACT

Meditation refers to a family of practices that may share many similarities, but can have differences in underlying methods and goals. Religious and spiritual associations are common but are not requisite for meditation practice and it should be recognized that the basis of many if not all practices is the training of the brain and body, a process that appears to have profound effects on both structure and function. In recent decades there has been interest regarding the effects of these ancient practices on the cardiovascular system, as meditation has intuitive appeal for benefit in this area. Though there is a relative shortage of quality data, available evidence suggests that meditation may exert beneficial effects on autonomic tone, autonomic reflexes, and decrease blood pressure acutely and after long term practice. In addition, meditation has the potential to positively influence the cardiovascular system through the mind–heart connection and the anti-inflammatory reflex. There is limited but promising data to suggest that meditation based interventions can have beneficial effects on patients with established cardiovascular disease. More high quality and unbiased studies of meditation practices on relevant endpoints in cardiovascular disease are needed, including the effects of such practices on inflammation, baseline heart rate variability, arrhythmias, myocardial infarction, and cardiovascular mortality.

1. Introduction

Meditation refers to a family of practices that may share many similarities, but can have differences in underlying methods and goals. The absence of a succinct yet thorough definition of meditation as well as a lack of exposure likely contribute to misconceptions regarding the practices in both the lay and scientific communities. The initial goal here is not to attempt the daunting task of providing a thorough definition of meditation or to introduce a classification system, but to give a brief overview of the building blocks of common meditation practices and how they might relate to the cardiovascular system and cardiovascular health.

Meditative practices may involve focused attention during which the practitioner directs his or her consciousness on breathing, an object, or a word or phrase known as a mantra. The focus of attention can also involve a greater awareness of all thoughts, emotions, and sensations that the individual has in a practice known as mindfulness meditation. Other practices strive to cultivate particular feelings such as love or compassion for self and others.

Many meditation practices place emphasis on experiencing the present moment. To counteract the natural tendency of the human mind to think about the past or future, skill in concentration is developed to allow the practitioner to focus primarily on immediate conscious phenomena. The inevitable wandering of the mind is acknowledged when it is noted to occur and attention is then directed back to where it is intended to be. This process occurs time and again and serves to strengthen concentration and ultimately the connection with the present moment. In more intense practices, the mental state of "thoughtless awareness" with a deep sense of physical and mental calm and enhanced pure awareness may result [1].

Though most often associated with Buddhism and Hinduism, meditative practices are also found in many if not all of the major religions of the world. Often, such practices include specific content that is related to the religious tradition. However, meditation practices may have spiritual meaning for those that practice in the absence of a formal religious belief system. Many practices today, including mindfulness or yoga based practices, are quite secularized compared to their traditions of origin. Thus, religious and spiritual associations are not requisite for practice and it should be recognized that the basis of many if not all practices is the training of the brain and body, a process that appears to have profound effects on both structure and function.

For thousands of years those that practice meditation have believed in the beneficial effects on the mind and body. Within the last half century, there has been an increase in scientific research that has studied the physiology of meditation practices and their effects in health and disease. There has been recent interest regarding

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the effects of meditation on the cardiovascular system, as meditation has intuitive appeal for benefit in this area. This review will explore the theoretical rationale and supporting data for the ability of meditation to exert a positive influence on the cardiovascular system and assess the current body of research on meditation in patients with cardiovascular disease. While movement based practices such as yoga or tai chi have meditative components, this review will focus on stationary meditation practices.

2. The autonomic nervous system

Chronic imbalance of the autonomic nervous system in the form of increased sympathetic tone and/or decreased parasympathetic tone is a powerful risk factor for cardiovascular morbidity and mortality [2,3]. Sympathetic activation increases cardiovascular workload and contributes to endothelial dysfunction, coronary spasm, left ventricular hypertrophy, myocardial infarction, arrhythmias, and sudden death [3]. Diverse factors that negatively affect the autonomic nervous system balance including insulin resistance and metabolic syndrome, sympathomimetic medications or recreational drugs, and acute and chronic psychosocial stressors are associated with increased risk of cardiovascular events. Conversely, therapies that offer a more favorable autonomic balance such as exercise, beta-blockers, and angiotensin converting enzyme inhibitors can reduce cardiovascular morbidity and mortality [3]. Described as a wakeful hypometabolic state [4], meditation practices can acutely exert significant influence on autonomic tone with parasympathetic activation [5]. The regular practice of meditation may favorably affect baseline autonomic balance [6], though this requires further study.

3. Heart rate variability and autonomic reflexes

Heart rate variability, a measure of the variation of instantaneous heart rate over time, can provide a window into the functioning of the autonomic nervous system and autonomic balance. Low heart rate variability has been associated with increased risk of cardiovascular events and mortality, and has also been associated with a poor prognosis in heart failure and post myocardial infarction [7–11]. Increased HRV appears cardioprotective in most, but not all groups (for example, those with sinus node dysfunction), as demonstrated in the Rotterdam Study [12].

Three sub-bands of heart rate variability of particular interest include high frequency oscillations (0.15–0.4 Hz), low frequency oscillations (0.04–0.15 Hz), and very low frequency oscillations (0.0033–0.04 Hz) [13]. A thorough discussion of heart rate variability is outside the scope of this review, therefore only the more relevant points will be discussed here. Respiratory sinus arrhythmia (RSA) is the normal physiologic phenomenon during which the heart rate increases with inspiration and decreases with expiration. As vagal activity is a major contributor to RSA, the phenomenon has been utilized as a marker of parasympathetic tone [13]. At normal breathing rates, these respiratory oscillations fall into the high frequency sub-band and consequently high frequency heart rate variability is thought to reflect parasympathetic tone. The origin of inherent low frequency oscillations is controversial but the dominant theory postulates that the baroreflex is responsible for low frequency variation through a feedback loop while another theory holds that low frequency oscillations are generated by a central brain stem oscillator [14]. Interpretation of the significance of low frequency oscillations is also controversial; low frequency variability is thought to reflect either autonomic balance or sympathetic activity. The significance of very low frequency oscillations is uncertain [13].

During meditation, the respiratory rate commonly decreases and heart rate variability from RSA may decrease to the low frequency range of heart rate variability. At approximately 6 breaths per minute or 0.1 Hz, RSA synchronizes with inherent low frequency variability leading to significantly increased amplitude of heart rate variability [15–19] (Fig. 1). This is the same physiology that occurs during biofeedback training to increase heart rate variability [20]. A rate of breathing of 6 breaths per minute or 0.1 Hz also coincides with and augments the intrinsic blood pressure variation known as the Mayer wave [21], a complex phenomenon of autonomic activity that results in an approximately 10 second cycle (0.1 Hz or 6 per minute) of blood pressure [22]. Of interest, it has been shown that during recitation of the Ave Maria in Latin and during recitation of a yoga mantra subjects spontaneously decreased their respiratory rate to 6 breaths per minute, which augmented heart rate variability and Mayer wave amplitude and even resulted in rhythmic fluctuations in cerebral blood flow [21].

The significance of this entrainment of cardiovascular oscillations is not completely known, but breathing at 6 per minute has been shown to increase baroreflex sensitivity [23]. It is well established that baroreceptor abnormalities are associated with a poor prognosis in chronic heart failure and post-myocardial infarction [24,25]. Lower rates of breathing (approximately 6 breaths per minute) have been shown to increase baroreflex sensitivity in heart failure, hypertension, diabetic autonomic neuropathy, and healthy controls [26–28]. The baroreflex has a tonic influence on the chemoreflex, and it has been demonstrated that an enhanced baroreflex inhibits the chemoreflex while a depressed baroreflex results in an augmented chemoreflex [23]. Slow deep breathing, through baroreflex augmentation, has been demonstrated to inhibit chemoreflex sensitivity with subsequent decrease of sympathetic tone [23]. Research is needed to determine if regular meditation or slow breathing can over time increase baseline heart rate variability and baroreflex sensitivity through favorably affecting baseline autonomic tone.

4. The anti-inflammatory reflex

Inflammation appears to play a central role in atherosclerotic plaque progression, vulnerability, and thrombogenicity [29,30], and has been implicated in the pathophysiology of heart failure [2]. Data suggests that the vagus nerve represents the efferent and afferent limbs of a cholinergic anti-inflammatory reflex that serves to decrease the detrimental effects of excessive proinflammatory stimulation [31]. Vagal afferents sense peripheral inflammation and transmit action potentials from the periphery to the brain stem. Efferent vagal activity is then enhanced and information relayed to the spleen and other organs where proinflammatory cytokines are inhibited and inflammation is limited [31–33] (Fig. 2).

In addition to giving us a window into vagal efferent activity to the heart and parasympathetic tone, heart rate variability may also give us insight into the activity of the anti-inflammatory reflex. Heart rate variability has been shown to be inversely related to inflammatory markers such as C-reactive protein and interleukin-6 (IL-6) [34,35], which is likely reflective of a direct but complex relationship between vagal efferent activity to the heart and the efferent arm of the anti-inflammatory reflex. Evidence suggests that the beneficial effects of exercise may be mediated, at least in part, through this anti-inflammatory reflex [36]. The potential favorable effects of meditation on autonomic tone have the potential to produce similar beneficial effects through this reflex, though to date data is limited.

5. The mind–heart connection

The mind–heart connection is a complex and powerful relationship. Brain injury is a well documented cause of dramatic electrocardiographic changes and cardiac lesions can result from disease of the central nervous system [37]. Acute emotional stress has been associated with myocardial infarction, Takutsubo cardiomyopathy, arrhythmias, and sudden cardiac death, while chronic stress at work or at home has been associated with increased risk of incident

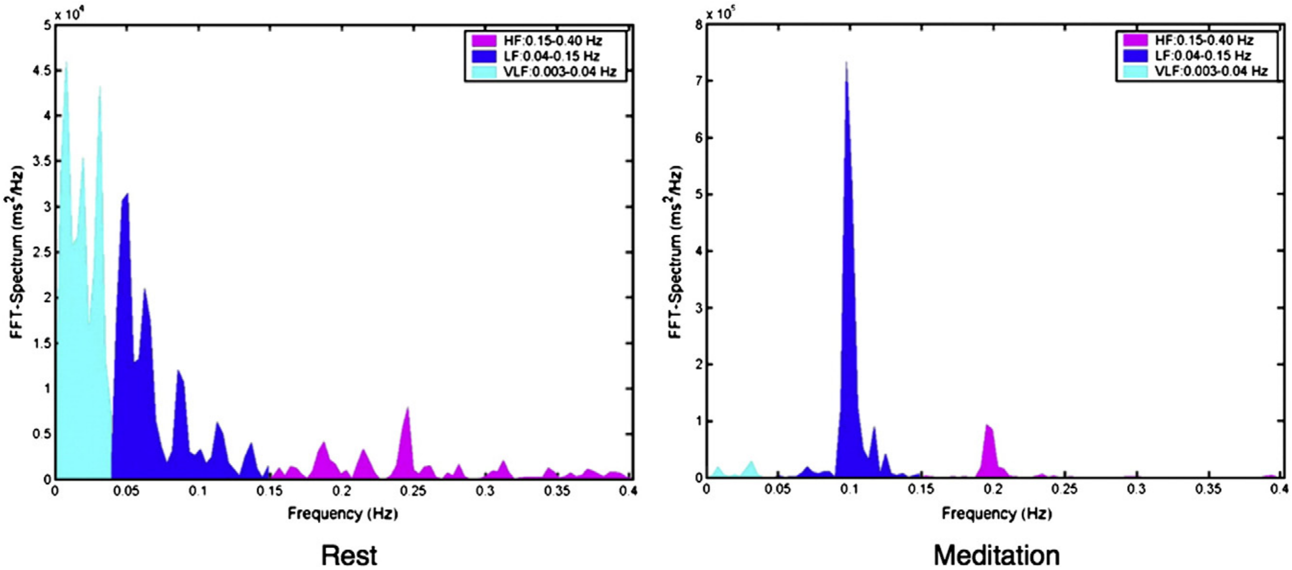

Fig. 1. Amplitude of heart rate variability sub-bands (high frequency, low frequency, and very low frequency) during quiet sitting and deep meditation. During quiet sitting heart rate variability is dispersed across the different frequencies. During meditation in this subject, the appearance of a resonant peak with high amplitude occurs at a frequency of 0.1 Hz, likely related to breathing at the same rate.
Modified with permission from Phongsuphap S, Pongsupap Y, Chandanamattha P, Lursinsap C. Changes in heart rate variability during concentration meditation. *Int J Cardiol*. 2008 Nov 28;130(3):481–4.

cardiovascular disease [38–42]. Anxiety and depression have been associated with increased risk of cardiovascular disease and are common in those with established cardiovascular disease; their added presence in established cardiovascular disease confers a poorer prognosis [40,41,43–48].

There is a growing body of research which describes the mechanisms of mind–heart interactions. The autonomic nervous system is one of the principal components of the mind–heart connection and is one of the fundamental links between thoughts and emotions and the heart [2]. The anti-inflammatory reflex provides an example of how autonomic function and inflammation interact and contribute to the mind–body communication network [2].

Major depressive disorder provides a good example of mind–heart interactions. Depression has been associated with sympathetic activation, decreased heart rate variability, and a proinflammatory response evidenced by increased inflammatory cytokines and C-reactive protein [2,49]. In addition, depression activates the hypothalamic-pituitary adrenocortical (HPA) axis increasing cortisol production leading to insulin resistance, hypertension, and increased cardiovascular risk. These factors create an environment that promotes

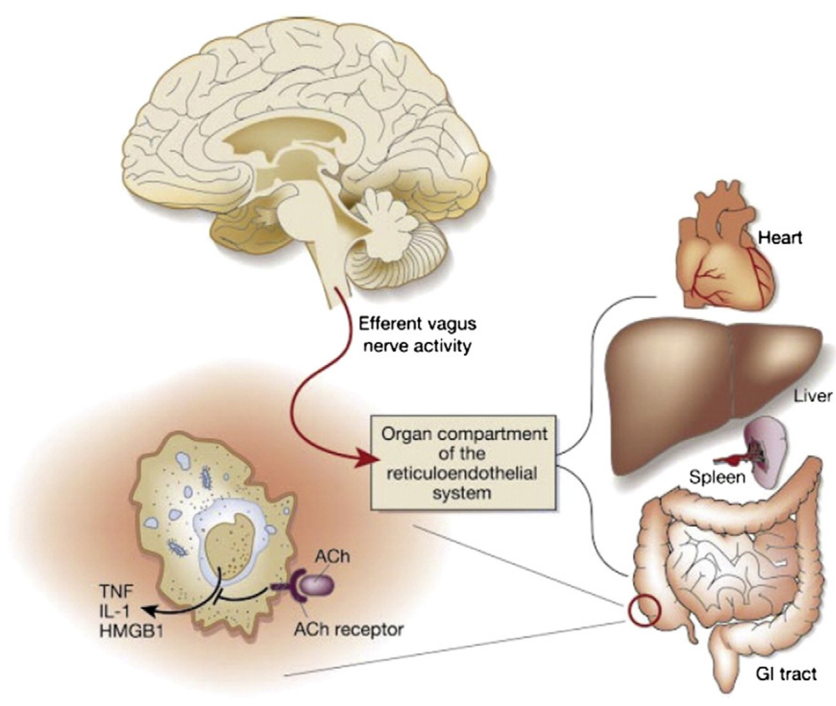

Fig. 2. Efferent limb of the anti-inflammatory reflex. Efferent vagal activity leads to acetylcholine (ACh) release in organs of the reticuloendothelial system resulting in inhibition of pro-inflammatory cytokine release by tissue macrophages.
Reprinted with permission from Tracey KJ. The inflammatory reflex. *Nature*. 2002 Dec 19–26;420(6917):853–9.

vasoconstriction, endothelial damage, adhesion molecule expression, and platelet aggregation leading to increased risk of coronary artery disease, myocardial infarction, arrhythmias, heart failure, and sudden death [2,40].

Conversely, autonomic dysfunction and inflammation in the periphery have effects on the central nervous system. It is known that pro-inflammatory stimulation has been associated with cognitive and mood changes as seen in the clinical example of interferon alpha induced depression [2]. Autonomic imbalance and inflammation in chronic cardiac disease may contribute to cognitive and mood changes in diseases such as congestive heart failure [2]. Further, an individual with autonomic dysfunction and inflammation as part of their inherent physiology may be at risk for both disorders of the mind and the cardiovascular system.

Subjectively reported benefits of long term meditation include relaxation and stress relief, increased concentration and attention, increased self-control, positive mood, emotional stability, increased resiliency to stress and negative events, as well as an overall enhanced psycho-emotional balance [1]. Objectively, there is evidence for meditation induced effects in the short and the long term on functional and structural brain plasticity as well as beneficial effects on relaxation and stress relief. There is also preliminary evidence for enhanced psycho-emotional balance and focused attention skills in those who practice meditation long term [1]. In addition, there is promising data on the effects of meditation for disorders of mood and anxiety [1]. Though very limited, data also suggests that meditation may result in improved psychological, hemodynamic, and immune responses to acute stress [50,51].

As meditation has probable beneficial effects on the mind and the autonomic nervous system, the practice may have a beneficial effect on the cardiovascular system. Data are limited but promising on the effects of psychosocial interventions in cardiovascular disease [40,41,52]. Though not meditation based, a randomized controlled trial in women with coronary artery disease found that a group stress reduction program including relaxation training may prolong life independent of other prognostic factors [52].

6. Blood pressure

6.1. Acute effects

The practice of meditation is associated with slower rates of breathing. Slower breathing rates, independent of meditation, have been shown to acutely decrease blood pressure, an effect mediated at least in part through modulation of central and peripheral autonomic tone [23]. Slow and controlled breathing at 6 breaths per minute has been demonstrated to significantly reduce the blood pressure of hypertensive subjects as well as in chronic heart failure subjects [26,27].

Transcendental meditation® (TM®) is a widely used and researched meditation program where a word or phrase is mentally repeated as an object of focus. TM® has been shown to decrease systolic blood pressure by 2.5 mm Hg acutely in long term practitioners during practice [53]. However, no acute effect on blood pressure was seen in a study of a similar meditation practice in healthy subjects during a long meditation [54]. It was hypothesized that this negative result may have been due to achievement of optimal blood pressure at baseline, as the baseline blood pressures were less than national averages.

Factors that likely affect the acute blood pressure response to meditation include baseline sympathetic and parasympathetic tone, systemic vascular resistance, cardiac output, as well as skill in achieving a meditative state. It is possible that those with baseline elevated systemic vascular resistance and/or autonomic imbalance may have a more dramatic acute effect. Ambulatory blood pressure recording of a hypertensive woman who practiced TM® showed a marked decrease in pressure during her meditation practice [55] (Fig. 3).

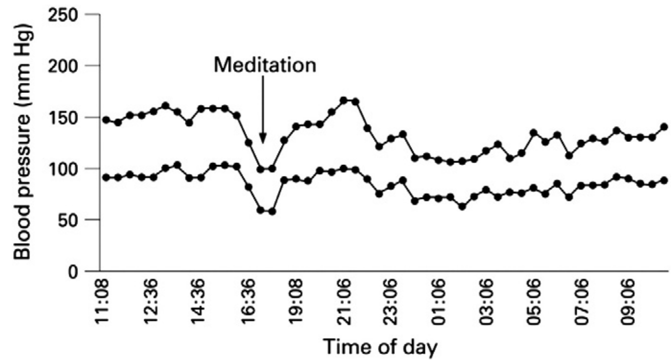

Fig. 3. Ambulatory blood pressure monitoring of a hypertensive woman that had a striking daytime blood pressure decrease to values lower than those during sleep. Upon review, the decrease corresponded to the woman's meditation practice. Reprinted with permission from Dear JW, Gough K, Webb, DJ. Images in medicine. Transcendental Meditation and Hypertension. *Postgrad Med J*. 2008;84:417.

6.2. Chronic effects

Early studies demonstrated chronic reductions in blood pressure with meditation practice that disappeared relatively quickly after discontinuation of the practice [56,57]. The effect of regular practice of TM® on baseline blood pressure has received considerable attention in recent decades. Trials of TM® in those with normal blood pressure and those with hypertension have demonstrated significant reductions of systolic and diastolic pressures [56,58–61]. However, many studies on TM® have been criticized for their quality and possible researcher bias [62,63].

Three studies considered higher quality utilizing TM® demonstrated: 1. a 3.4 mm Hg reduction in systolic pressure with no significant change in diastolic pressure in patients with coronary artery disease; 2. a 10.7 mm Hg systolic reduction and 6.4 mm Hg diastolic reduction in African American adults with hypertension; and 3. a non-significant 3.1 mm Hg systolic reduction with a significant 5.7 mm Hg diastolic reduction again in African Americans with hypertension [64–67]. In a 2009 study of TM® in college students, meditation did not have a significant effect on the blood pressure in the overall group. However, in the group at high risk for hypertension, meditation significantly decreased systolic pressure by 5.0 mm Hg and diastolic pressure by 2.8 mm Hg, compared to increases of 1.3 mm Hg systolic and 1.2 mm Hg diastolic in controls [68].

In a study of a contemplation meditation and breathing techniques in the treatment of pharmacologically untreated hypertension, office systolic pressure decreased by 15 mm Hg in the treatment group with no change noted in the control group [69]. The study utilized a very intensive intervention which included 40 min of meditation two times per day for 8 weeks. A limitation of this and many controlled studies on meditation is the potential effect of placebo, as no validated "sham meditation technique" exists.

7. Adrenal hormones

Intuitively, as meditation produces physiologic results opposite from stress, lower levels of plasma catecholamines would be expected in those that meditate. However, decreased levels of catecholamines in meditators have not been a consistent finding [56]. There is data to suggest that the relaxation response may reduce the responsiveness of end organs to catecholamines [56]. Decreased cortisol levels in those that meditate have been a more consistent finding [6,56].

A small study investigated the effects of meditation on norepinephrine levels in 19 elderly patients with chronic heart failure with both reduced and preserved ejection fraction [70]. The meditation group was provided instruction in meditation and a 30 minute audiotape with meditation instructions to listen to twice per day for 12 weeks plus a weekly meeting, while the control group had only weekly meetings. After the intervention, the meditation group significantly decreased their norepinephrine levels, a result not noted in the control group. Though promising, the study has limitations including a small sample size and higher baseline norepinephrine levels in the meditation group.

8. Slow breathing, ventilation, and exercise capacity in heart failure

Respiratory dysfunction has been documented in congestive heart failure and can contribute to decreased exercise tolerance [71–73]. In a study of 50 heart failure patients and 11 controls, Bernardi and colleagues found that slow breathing at 6 breaths per minute increased oxygen saturation in heart failure patients, with evidence to suggest that this rate was more effective in terms of gas exchange [71]. In a follow-up study, 15 of the heart failure patients were assigned to one month of respiratory training or rest. The goal of the training was to reduce the breathing rate and to mobilize in sequence the diaphragm, the lower chest, and the upper chest during inspiration with the reverse during expiration. Patients underwent symptom-limited upright bicycle cardiopulmonary exercise testing before and after the training. After one month of respiratory training, respiratory rate decreased from 13.4 (1.5) to 7.6 (1.9) ($p < 0.001$), peak oxygen consumption increased from 1157 (83) to 1368 (110) L/min ($p < 0.05$), and exercise time increased from 583 (29) to 615 (23) min/s ($p < 0.05$); changes that were not seen in the control group [71]. Although the study is limited by a small size, it does suggest the potential for respiratory training to improve exercise tolerance in heart failure.

9. Clinical trials in established cardiovascular disease

Data on the effects of meditation on clinical endpoints in established cardiovascular disease are limited. A small study (23 total patients) examined the effects of TM® in African Americans (≥55 years) with NYHA class II or III congestive heart failure and ejection fraction less than 40% [74]. Subjects were randomized to instruction in TM® and two 15–20 min at home sessions of meditation per day or health education classes with instructions to read or listen to music for 15–20 min two times per day. The meditation group had significant improvements in the primary endpoint of six-minute walk test scores, improving their six-minute walk test score by 50.5 m from baseline to 6 months compared to the health education group who had a decreased six-minute walk test score by 6.2 m at 6 months ($p = 0.03$). There were also improvements in quality of life and depression in the meditation group. Limitations of the study include the very small sample size and short follow-up.

The Support Education and Research in Chronic Heart Failure Study (SEARCH) trial demonstrated promise for the role of meditation and mindfulness therapy in the treatment of heart failure [75]. SEARCH was a prospective cohort study of 208 adults with left ventricular systolic dysfunction (ejection fraction less than or equal to 40%) and symptoms of congestive heart failure. Patients were geographically assigned to either usual care or 2.25 hour weekly meetings in an 8 week course that included mindfulness and meditation training using mindfulness based stress reduction (MBSR) concepts, training in coping skills, and support group discussion. Audiotapes with instructions for guided meditations were provided and patients in the treatment group agreed to practice these skills daily for 30 min. Outcome measures were designed to evaluate effects on depression, psychosocial distress, and heart failure symptoms. The mean age was 61, 70% of the patients were male, 46% had an ischemic etiology for their cardiomyopathy, and mean ejection fraction was 26%. The treatment group had significantly improved symptoms of heart failure at one year compared to the control group. Those in the treatment group also had significantly lower levels of anxiety and depression; an effect that was attenuated at one year. A limitation of the study was that the treatment group assignments were made by geography and not randomization. More recently, TM® was found to decrease a composite of all-cause mortality, myocardial infarction, or stroke in African American patients with coronary heart disease [76]. Though the results appear promising, analysis of the study and the statistics utilized raise questions making the data at best less than robust.

10. Conclusion

Theoretical rationale and supporting data exist illustrating the potential of meditation practices to exert significant benefits on the cardiovascular system. As our goals are to help patients live better and longer, there appears to be sufficient evidence regarding meditation practices to recommend them based on the former. More high quality and unbiased studies of meditation practices on relevant endpoints in cardiovascular disease are needed including the effects of such practices on inflammation, baseline heart rate variability, arrhythmias, myocardial infarction, and cardiovascular mortality. These studies may establish meditation as a beneficial adjunctive therapy in the prevention and treatment of cardiovascular disease.

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