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Short Communication

Cardiac Output as Information

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Abstract

Cardiac output appears to have an informational aspect apart from just enabling the circulation of nutrients and blood components. End-organs receiving this information (kidneys, baroreceptors) react to this information in both normal cardiac function and in diseased states such as congestive heart failure. The kidneys may increase or decrease salt and water retention, and the sympathetic nervous system may be activated or scaled down. The concept introduced in this paper is based on ideas from information theory, such as entropy. It may better promote our understanding of circulatory physiology, and possibly help clinicians in managing patient care.

Keywords: *Cardiac output information.*

INTRODUCTION

In the middle of the last century, several investigators including Nyquist, Hartley, and Shannon, working in telecommunications, began to look at entropy as a measure of information-- not knowledge, content, or meaning, but as degree of uncertainty. Shannon entropy measures the uncertainty of a probability distribution (1):

$$H = \sum_{i=1}^{N} P \log (1/P) \qquad (1.1)$$

This is done in the setting of a sender, a channel, and a receiver of information. High information signals have high entropy, are complex and unpredictable, have a high degree of variability, a low probability of a selected event, and are surprising to the receiver. Low information signals have the opposite of these, they are monotonous, and have a high probability of a selected event (low uncertainty).

METHODS AND RESULTS

The normal healthy heart is capable of great variability in rate, stroke volume, and cardiac output. This results in high entropy; high information signals being sent to the various receivers (end organs such as the kidney, receptors, and sympathetic nervous system). This is in contrast to cardiomyopathy (CHF) with low ejection fraction and poor systolic function, where the rate, stroke volume, and cardiac output are reduced and show much less variability, especially in response to physiologic stress. These are low entropy, low information content signals (2).

FIGURE 1

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Normal heart: high entropy, high variability, high information content

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Cardiomyopathy: low entropy, low variability, low information content Sender (heart)-----Channel (arterial system)----- Receivers (kidney, baro- receptors, sympathetic tone).

Discussion

In good health, the receivers constantly receive new and often unexpected information, which they react to by constantly changing their retention or excretion of salt and water, and the level of sympathetic tone. In CHF, they receive steady low information, and expected signals, so they respond by continuing to retain salt and water, and high sympathetic output resulting in continuous CHF symptoms (3).

Conclusion

Thus, the information content of cardiac output looked at in this way, may be relevant to our understanding of cardiac physiology and pathophysiology. Detection of a change from high information content signals to low information content may alert the clinician to a worsening of a patient's cardiac function. A change from low to high information signals may indicate improvement, possibly due to an intervention or drug treatment.

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