

Neurocardiology as Integrative Science: Coordination with Traditional Chinese Medicine

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Abstract: Neurocardiology is a new multidisciplinary field that combines insights from cardiology and neurology with engineering techniques of signal processing and analysis. Mainly, it is oriented on evaluation of the influence of autonomic nervous system (ANS) on cardiac functions. Diversity of publications in neurocardiac research indicates that this scientific field is very complementary with other sciences like pharmacology, nanotechnologies, other branches of internal medicine and especially with Traditional Chinese Medicine (TCM). This article is giving introduction to main principles of neurocardiology, overview of collaborations between neurocardiology and TCM and general interpretation of neurocardiac findings in the context of TCM concepts. With our preliminary research we want to indicate that the state of ANS might be significant assumption for effectiveness of drug and acupuncture therapy.

Index Terms: sympathetic ANS, parasympathetic ANS, Heart rate variability, yin, yang, acupuncture

Introduction. Probably the first definition of Neurocardiology was introduced as early as in 1960s and states that it is a combination of neurology and cardiology or neurosciences and cardiovascular physiology [1]. Originally, neurocardiac conception have spontaneously appeared since cardiologists and neurologists started to consult with each other in clinical situations where cardiac diseases are followed by neurological complications or vice versa, in presence of heart abnormalities and their influence on the neurological conditions and diseases [2]. Then, that concept evolved with progress in clinical and experimental research and implementation of specialized ECG (monitoring) instrumentation and software. In recent years it became fruitful area for application of multivariable calculation algorithms, artificial intelligence [3] and software with graphical interfaces [4]. This lead to modern concept of Neurocardiology that provides detailed (systematic) diagnostics of each patient and individual optimization of therapy because of which it is characterized as personalized medical approach [5]. Nowadays, Neurocardiology is mostly refered on evaluation of ANS and cardiovascular inter-influences by means of ECG and blood pressure signal analysis in various medical conditions¹. Beside clinical significance, Neurocardiology contain great research potential. It can spread easy attaching “synapses” and “veins” to connect with other medical and scientific

¹ Except Neurocardiology that deals with ANS influence on cardiac functions, there are two more kinds of Neurocardiology that are developing in past few decades. Those are: Neurocardiology that research relations between brain and heart as well as intermeshing of neurologic and cardiologic problems [1,2,6,7]; and Neurocardiology that research intrinsic cardiac nervous system and neural features of heart [8,9].

branches such as biomedical engineering, nanotechnologies and pharmacology and many other biomedical fields. For the last two decades there is increased interest for breakthroughs between Neurocardiology and Traditional Chinese Medicine (TCM). Their principles are very complementary, as it will be presented later. Main common topic connecting these two fields is the influence of acupuncture on autonomic nervous system (ANS). Articles about it are in publishing expansion not just in magazines for Alternative and Complementary Medicine, but also in renowned classical scientific journals. For mastering over methods and approaches of integration Neurocardiology and TCM it is preferable first to get introduced with their most important terms.

Neurocardiology and TCM. Many concepts of TCM are almost untranslatable or without analogons in classical medicine. Such are Qi, 气 (qì), Yin 阴 (yīn) and Yang 阳 (yáng). With exploring their etymologies we can understand better of what they are [10, p.19-21]. During anamnesis and diagnosis TCM physicians are getting multifactorial analysis to construct image of impairment in body or organic dysfunction. In the same time they are trying to find out the cause of disease. Their results are usually expressed in terms like “blockage of qi flow” or “excess/deficit of yin/yang” have lead to illness [10, p. 20]. To answer on it, they have established therapeutic techniques, all of which are based on, the so called, liqi, 理气 (lǐqì) – regulation of qi and reparation of its flow blockages and balancing of yin and yang disturbances [10, p. 23]. It turns out that TCM concepts are highly complementary with findings in biomedical field of Neurocardiology. As well known, sympathetic ANS (sANS) is increasing physiological functions (heart rate, blood pressure), whereas parasympathetic ANS (pANS) is decreasing it. As a rule, sANS and pANS are always acting antagonistic, synchronous, synergetic; they never act independently, action of one is always followed with inhibition of other [11]. These ANS system regulation concepts are similarly explained by Zhang Fu 脏腑 (zàngfǔ) theory of inner organs in TCM [10, p. 23]. Thus, sANS and pANS are suitable to be modeled as yang and yin. Translated to language of Neurocardiology TCM principles could mean: organic dysfunctions and syndromes 证 (zhèng) [10, p. 22-23] are related to impairment of ANS control over involuntary functions. Qi congestion could mean impairment of autonomic regulation (very low total power of HRV spectrum); yang excess can be regarded as sympathetic predominance (high value of LF band in TP spectrum of HRV), and yin excess as parasympathetic predominance (high value of HF band in TP spectrum of HRV). Mentioned analogies are suggesting that TCM and neurocardiology have similar systematic approaches. TCM-Neurocard analogies can further be confirmed by visual presentation and analysis of neurocardiac signals. These are not just conceptual analogies, but it might have clinical significance in the sense of practical integrative approach of Neurocardiology and TCM. Briefly, this idea is going to be explained in next sections.

Neurocard-TCM algorithms. In modern neurocardiac TCM related research attention is usually made on influence of acupuncture on ANS. We came on idea to evaluate opposite principle. Thus, main hypothesis confirmed in our preliminary research is that effectiveness of drug therapy depends from state of ANS. We characterized state of ANS by combination of several neurocardiac parameters. We divided states of ANS on even (2, 4, 8, 12) and uneven

groups (3, 5, 9 etc) in correspondence with Yi Jing 易经 (yìjīng), Chinese Book of Changes. Each group was determined by ranges of parameters in combination such as LF (low/high, very low/very high – for even groups, and low/moderate/high – for uneven groups) with TP (low/high, very low/very high). Therapeutic effect was determined as drop in pressure (for hypertension), better pressure regulation in syncope and orthostatic hypotension. Correlation of certain states of ANS with significant therapeutic effects of several drugs was found. All classifications on groups and statistical compilation were performed in SPSS software using SPSS syntax for each diagnostic group. Based on these autonomic patterns and correlations with therapeutic effects we are developing algorithm for recommendation of drug therapy. In the similar manner we started to evaluate these principles for the influence of the state of ANS on effectiveness of acupuncture therapy. We are going to demonstrate this on two examples. In the first hypertensive patient we measured HRV and BPV parameters before acupuncture. From it we calculated LF_RRI, HF_RRI and VLF_RRI bands. This patient had sympathetic predominance with low total power.

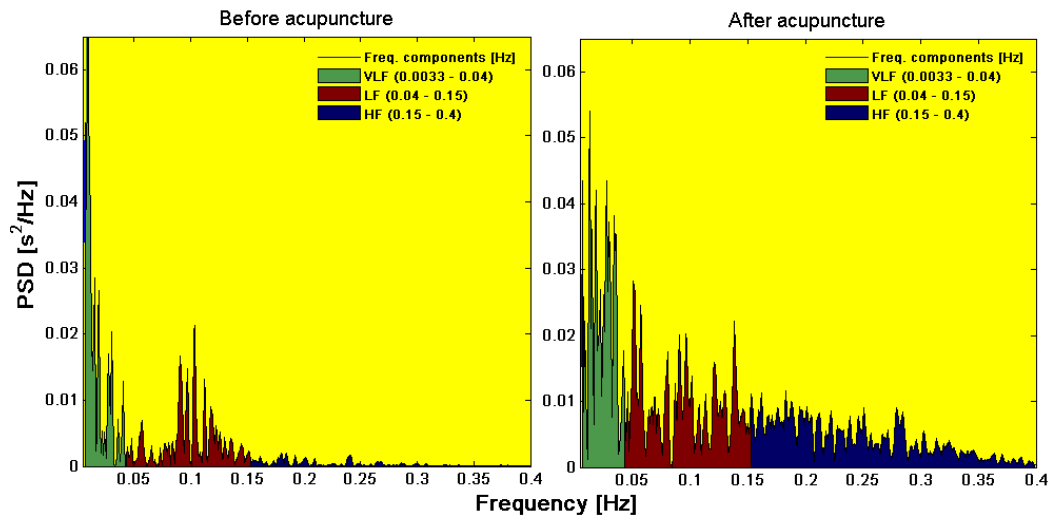


Fig. 1: HRV spectra calculated by FFT based non-parametric algorithm. Power of VLF, LF and HF are indicated by colored areas. Left graph is done for HRV before acupuncture, and right graph is done for HRV after acupuncture.

Table 1: Parameters of PSD spectrum before and after acupuncture therapy

Par	Units	Before acupuncture	After acupuncture	Difference (%)
VLF	ms ²	686	907	32.2
LF	ms ²	395	1027	260.0
HF	ms ²	78	1023	1311.5
TP	ms ²	1159	2957	155.1
LF/HF	-	5.014	1.004	-499.4
LFnu	%	83.37	50.09	-39.9
Hfnu	%	16.63	49.9	300.1

After administration of 7 days long acupuncture therapy, drop of mean values of HRV (14%↓) sBPV (4%↓), mBPV (9%↓), and dBPV (9%↓) was observed.

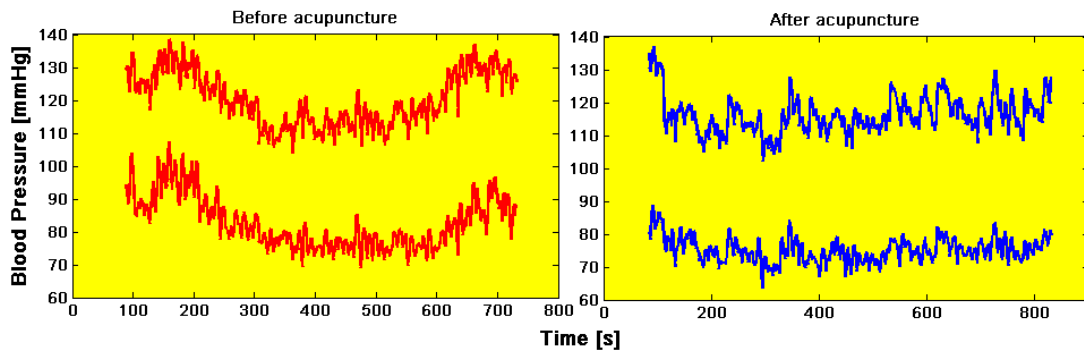


Fig. 2: Systolic and diastolic BPV signals plotted for 10 minutes of recording in the rest; red plot: before acupuncture; blue plot: after 7 days of acupuncture treatments [12].

Then, we repeated the same procedure in a hypertensive patient that had parasympathetic predominance with high total power. There was no therapeutic effect on HRV and BPV signals neither for short term (during and after 15 min of acupuncture treatment) or long term (after 7 days of acupuncture treatments) experimental procedures. Then, almost accidentally we decided to try with opposite principle - to treat acupuncture points that are connected with vagus. Therapeutic effects were achieved in both short term and long term experimental procedures. This atypical case deserves one note: usually in hypertensive patient increased activation of sANS is rising blood pressure. Here, in this patient is opposite; increased pANS activity is cause of hypertension. This could be sign why acupuncture therapy is not effective in some people. Those are probably people with this kind of atypical ANS regulation. Thus, it is suitable to adjust acupuncture treatment in agreement with better ANS response.

Conclusion. Preliminary results presented in this paper are indicating that the states of ANS could serve as major indices for getting right therapeutic response in clinical settings. For more certain confirmation of this thesis it is necessary to conduct research on many more patients and volunteers. Also, more precise and narrower autonomic patterns should be derived from it with correspondences with positive and negative therapeutic responses. That is potential base for algorithm for recommendation of therapy. By means of signal processing it is possible to develop algorithm that is going to enable autonomic analysis from ordinary ECG signal recorded during short time period (e. g. 3 minutes and even less than 30 seconds). From that signal should follow determination of characteristic autonomic patterns that are contained in the signal. Instead of manual calculation and making classifications in SPSS program it is suitable to perform it with artificial neural networks (ANN). Code (algorithmic rule) obtained after training of ANN and testing accuracy, should be used in each ANS diagnostic procedure. Then, with algorithmic rule *if/then* it is easy to construct next algorithm: if certain state of ANS is characterized then certain drug or type of acupuncture therapy is recommended. Here, it would be favorable to add, so to call, neurocardiac anamnesis. Neurocardiac anamnesis is not something yet defined. But, physicians that do examination of patients with Task Force monitor devices for years are getting experience from which they can closely evaluate ANS type in patients from their symptoms, personal characteristics during conversation (energetic types signified from will, mood, gesticulation; e. g. hyperactive versus phlegmatic behavioral

manners). So, these (descriptive) parameters² indicating ANS predomination could also come into account to form an expert system for neurocardiac analysis³. Such expert system would be tool for support in clinical decisions (it would do mimetics of (neuro)cardiologist expertise, as good as possible). Also, it could be constructed like some expert systems for TCM [16,17]. But, like in TCM it is goal to predetermine, so to call, neurocardiac zheng (systematic (ANS) patterns specific for pathological health conditions). Thus, we were trying to find autonomic patterns typical for diseases. By means of more than 50 linear parameters applied on 17 datasets of signals of patients with different diagnoses it was not possible to discover clear autonomic patterns that can make distinguishing between each of diseases. We only succeeded to make difference in autonomic patters between diseases and healthy group⁴. But, we have not used nonlinear parameters in our research. Nonlinear parameters are more promising tools to give characteristic patterns for each disease. There is a claim that “nonlinear characteristics of HR and BP fluctuation are produced by autonomic nervous system” [18]. It is evaluated that the linear analysis tools, which up till now have been considered as the standard methods only describe about 15% of the total variability [18]. In the same reference quoted here, there is good analysis of linear and nonlinear patterns in characterisation of cardiovascular states. They showed that linear parameters could not succeeded to discriminate groups (normal from disturbed functioning), but nonlinear could! [18]. These are promising clues that neurocardiac zheng is possible. If that is so, there could be constructed software that will use ordinary short term ECG signal to make automatic analysis, diagnosis and recommendation of right therapy for each patient. That achievement would confirm that well measured synthesis of ancient experience and knowledge of Traditional Chinese Medicine with modern technical insights of Neurocardiology are ideal approach, much better then confrontation between each other.

² Using artificial neural networks it is possible to combine descriptive parameters with parameters of ANS analysis to make classifier of pathological and normal states with more than 98 % accuracy [13]

³ If some further research confirms equivalence of these patterns with patterns in zheng in TCM, they might become indices for distinguishing disturbed ANS from natural predomination and also for adjustment of therapy and recommendations for synchronization with native life rhythms (it could be also added as an option in software recommendation algorithm). Collected information should be than evaluated with prediction algorithm to give eventual predisposition for pathological development. These predisposition data are suitable for combination with clinical information in order to give notion of current health state and factors of risk for disease development and undesired events like stroke, heart failure, sudden death...

⁴ This is also known fact from other modern research: autonomic imbalance, in which typically the sympathetic system is hyperactive and the parasympathetic system is hypoactive, is often associated with various pathological conditions [14]. Changes in the HRV patterns could be an indicator of health status. High HRV is a signal of good adaptation and characterizes a healthy person with efficient autonomic mechanisms. Whilst lower HRV is frequently an indicator of abnormal and insufficient adaptation of the ANS, causing the subject low physiological function, this decrease is consistent with a dysfunctional vagus [15].

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