Tracking Dynamic Arterial Pressure Waveform on Vasoactive Medication Via Manifold Learning Method

Presenting Author: Yu-Ting Lin[a] MD,

Co-Authors: Te-Sheng Lin[b] PhD, Hau-tieng Wu[c] MD PhD, Cheng-Hsi Chang[d] MD, Shen-Chih Wang[a] MD, Ting Chien-Kun[a], MD

[a]Department of Anesthesiology, Taipei Veteran General Hospital, Taiwan
[b]Department of Applied Mathematics, National Chiao Tung University, Taiwan
[c]Department of Mathematics and Department of Statistical Science, Duke University,
[d]Department of Anesthesiology, Shin Kong Wu Ho-Su Memorial Hospital, Taiwan

Introduction: Vasoactive medication is an indispensable part of armament in daily anesthetic management. Besides anesthetics, anesthesiologists administer vasoactive medication to preserve brain perfusion, to protect myocardium, to control surgical bleeding, or to treat life-threatening shock. We assess their clinical effects on cardiovascular system, either vasodilation or vasoconstriction, by the blood pressure readings shown in the patient monitor. At the same time, the vasoactive medication also exerts effects on the morphology of the blood pressure pulse wave, which is more difficult to be perceived with the waveform displayed in the patient monitor. It is possible that the extra information carried in the morphology of blood pressure waveform may provide further understanding in cardiovascular physiology. That is, the same blood pressure value with different shape of the pulse wave may indicate different state of the cardiovascular system. It is also possible that the pulse waveform may provide further understanding to the pharmacological effect in physiology.

In this study, we use an unsupervised manifold learning method, diffusion map (DM), to analyze the blood pressure waveform signal recorded from patient monitor to analyze the dynamic waveform. The goal is to investigate the vasoactive effect on blood pressure waveform in high dimension space.

Methods: From physiological database collected for observational study, we analyzed the arterial blood pressure waveform during bolus dosage of vasoactive agents, which includes 12 epochs of data of nicardipine (1mg) as vasodilatory agents, 12 bolus doses of norepinephrine (10μg) as vasoconstrictive agents, and 6 bolus doses of ephedrine (8mg) as indirect pressor agents. These data segments are from patients undergoing major surgery and general anesthesia. DM is a new data analysis approach that treats every oscillatory cycle as a high dimensional data point; in other words, the pulse waveform during the surgery is converged into a large collection of high dimensional variables. DM works by finding a geometric structure in high dimensional space representing the collection of the pulse waveform to be observed. Being unaware of the medication, the temporal relationship, or any knowledge of the data except the waveform, this unsupervised method extracts dynamical information from the pulse waveform objectively.

Results: The three-dimensional embedding of the pulses from nicardipine, norepinephrine and ephedrine shows common direction and path, representing the pharmacological feature of vasodilatory, vasoconstrictive and the mixed pressor effects respectively. The 3-D

embeddings of nicardipine and norepinephrine demonstrate the contrarily directional movement of the common path, featuring the reciprocal effect between vasodilation and vasoconstriction. This phenomenon preserves after we remove the effect of blood pressure.

Conclusions:

Machine learning method can provide additional information regarding the pharmacological effects of vasoactive agents.

Images:

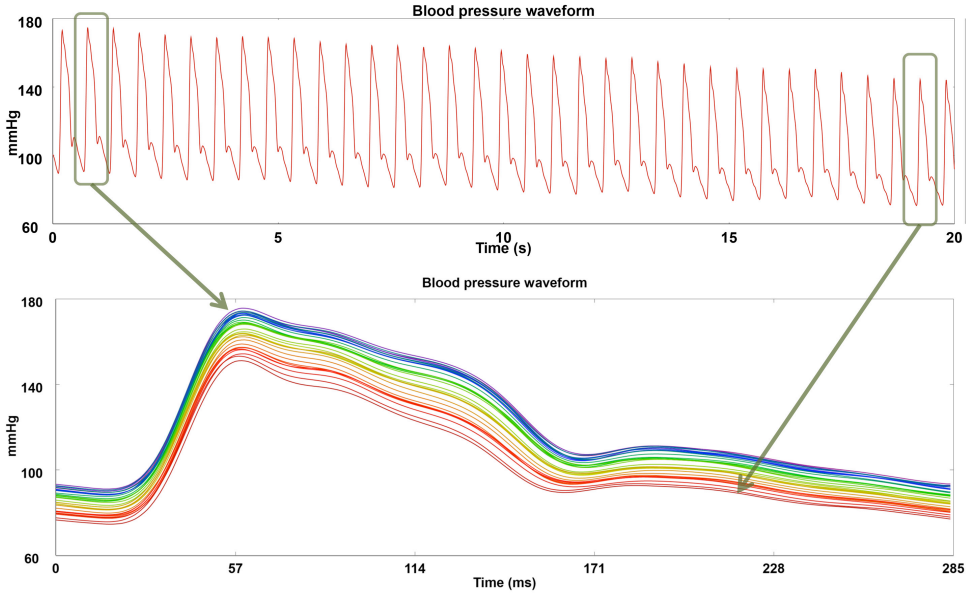

Figure1. Pulse waveforms from one epoch of blood pressure waveform on the bolus of nicardipine. Each pulse represents one data point in high dimensional space.

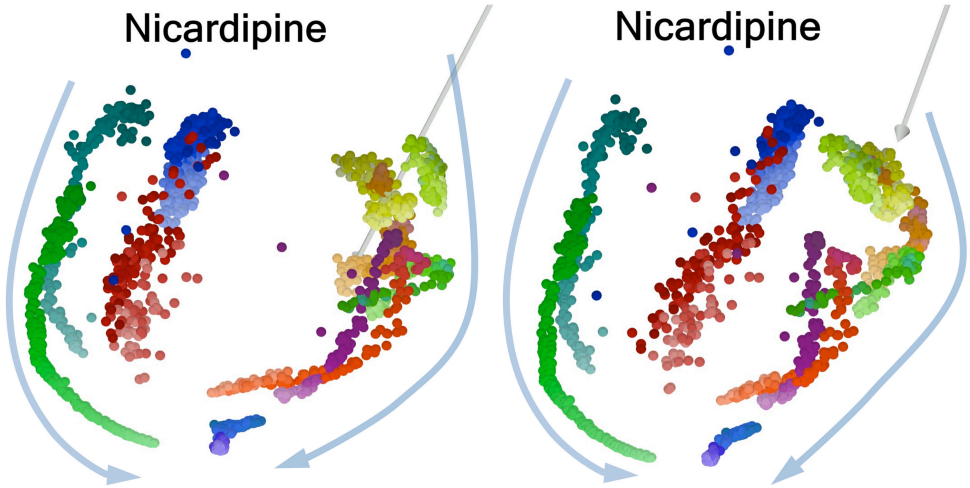

Figure 2. The 12 epochs of data show the common effect of nicardipine as the downward trend. Both graphs are the same 3-D embedding with merely a slight rotation. Blue arrows indicate the common downward direction. Different color represents different epoch of data, and the transition of darker to lighter color represents the evolving with time.

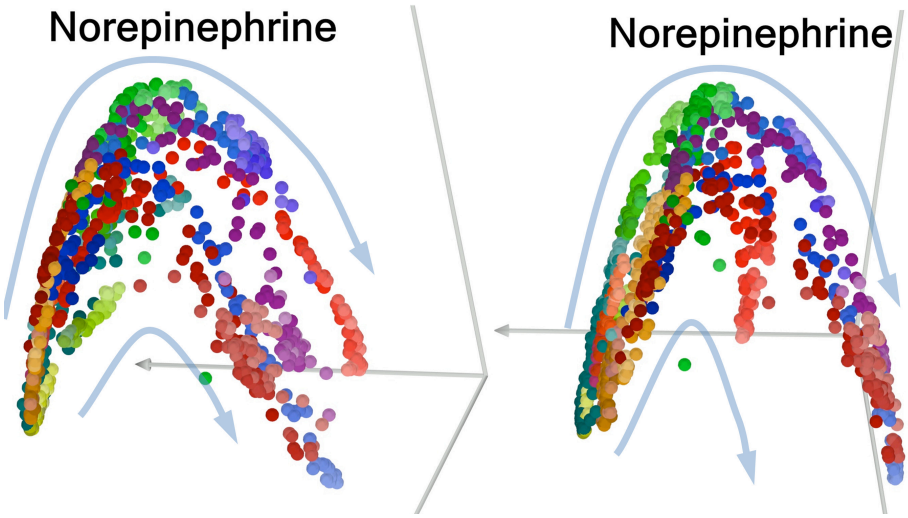

Figure 3. As the same representation of Fig.2, the 3-D embedding graphs show the common movement trend of norepinephrine. Both graphs are the same 3-D embedding with merely a slight rotation.

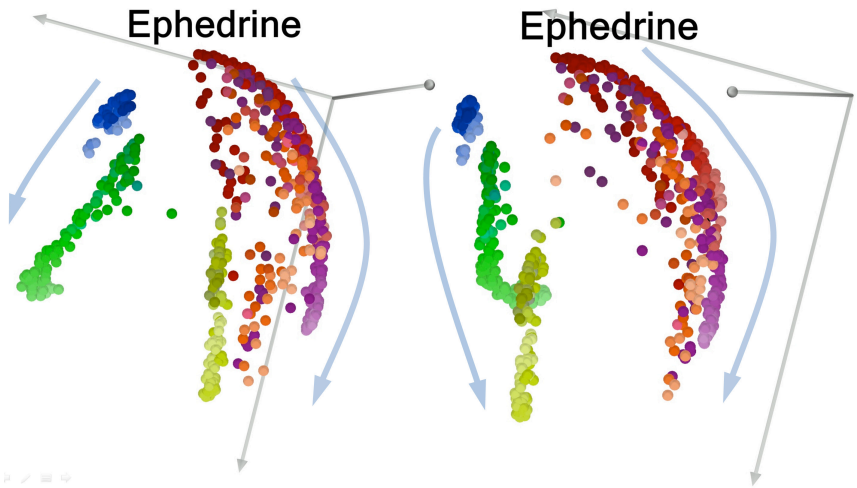

Figure 4. As the same representation of Fig.2, the 3-D embedding graphs show the common movement trend of ephedrine. Both graphs are the same 3-D embedding with merely a slight rotation.

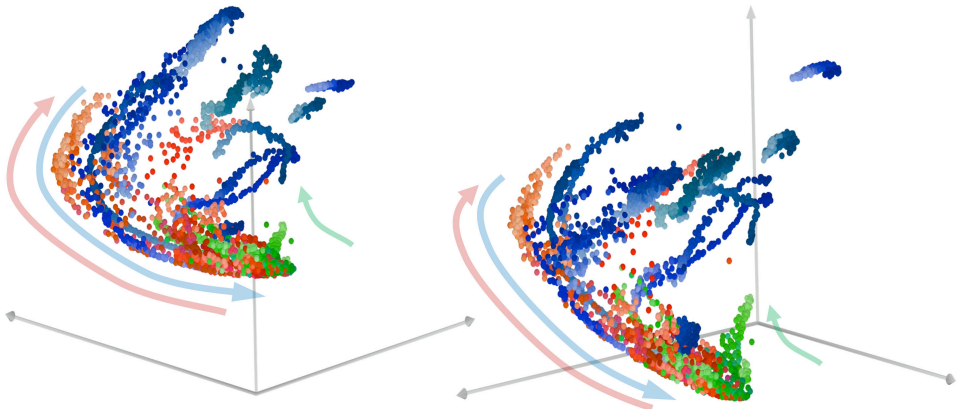

Figure 5. As the same representation of Fig.2, the 3-D embedding graphs show the combination of nicardipine (blue), ephedrine (green) and norepinephrine (red). Both graphs are the same 3-D embedding with merely a slight rotation. Blue arrow indicates common trend of nicardipine, which is contrary to red arrow indicating common trend of

norephnephrine. Green arrow indicates the slightly different direction of ephedrine.