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Noninvasive Continuous Monitoring of Stroke Volume during Fluid Challenge using Portable Electrical Impedance Tomography (EIT)

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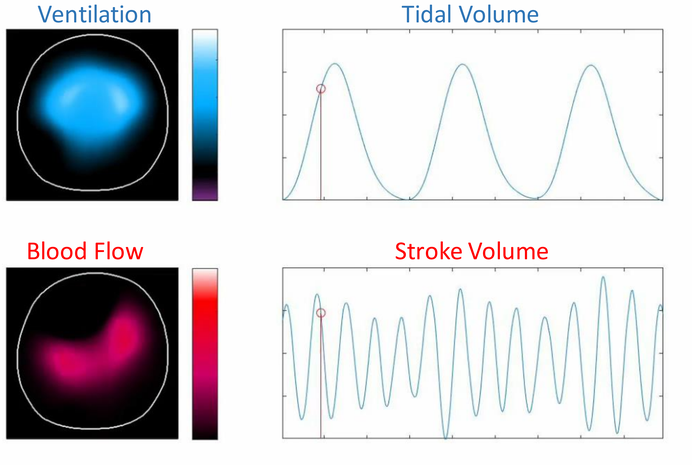
Background

Stroke volume (SV) and cardiac output (CO) are key indicators for monitoring hemodynamically-unstable patients. The current gold standard for CO measurements is the thermodilution method, which is an invasive and expensive procedure with only intermittent measurements. Accurate noninvasive continuous measurements of SV and CO would benefit many ICU and OR patients [1].

Methods

Four pigs (weights of 29 to 31 kg) were anesthetized and mechanically ventilated using Hamilton-G5 (Hamilton Medical, Switzerland). The air volume for normal ventilation was set to 8 ml/kg with a respiration rate of 20 bpm. SV was measured using EV1000 (Edwards Lifesciences, U.S.) in the pulse contour analysis (PCA) mode. A portable 16-channel electrical impedance tomography (EIT) device with 100 frames per second temporal resolution was simultaneously used with EV1000 to measure SV separately. The SV change signals were extracted from the reconstructed EIT images and calibrated to absolute volume in ml with the simultaneously acquired SV data using EV1000. After removing 30% of the total blood from each pig, ten 100-ml fluid challenges were conducted. The time for fluid injection was 1 min and the interval between consecutive fluid injections was 2 min. The experimental protocol was approved by the Institutional Animal Care and Use Committee (SMC-20150804001).



Results

The difference between the measured SV data using the transpulmonary thermodilution (TPTD) and EIT methods was ±4.7 ml. The difference between the amount of air supplied from the mechanical ventilator and the tidal volume data measured by the EIT method was ±11 ml. During PEEP maneuver from 0 to 16 cmH_2O and then back to 0 cmH_2O, the SV data measured by the EIT and PCA methods were well correlated showing decreased SV data at high PEEP values. During repeated 1-min 100-ml fluid challenges, both the EIT and PCA methods successfully tracked changes in SV during the volume responsiveness phase. EV1000 failed to measure SV when the blood pressure was low while EIT succeeded. Furthermore, EIT was able to measure decreased SV during the volume overload phase in some animals.

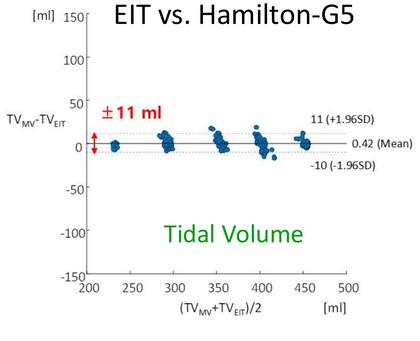
Conclusion

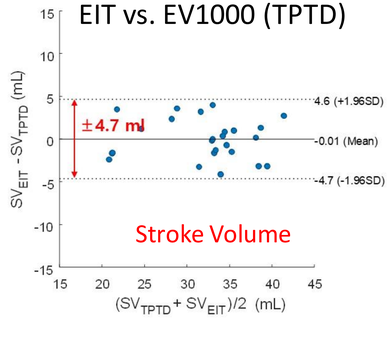
The EIT system successfully measured SV with good accuracy in our study with four pigs. More studies are needed to further validate the EIT method for conducting noninvasive continuous SV and CO monitoring in ICU, OR, and other places.

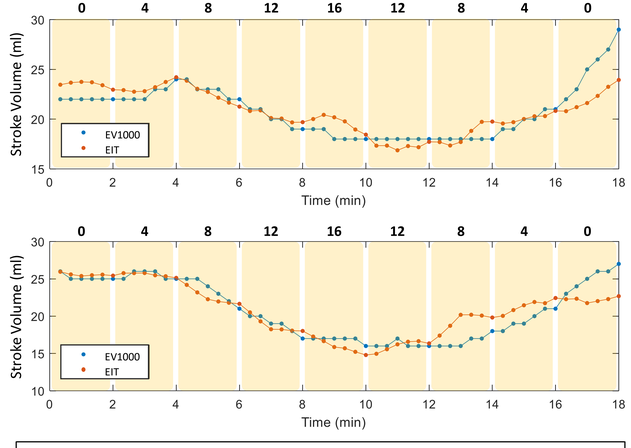
References

[1] Cecconi M, et al. Int. Care Med. 2015;41:1529-37.

[2] Wi H, et al. IEEE Trans. Biomed. Circuits Syst. 2014;8: 119–28.







Simultaneous stroke volume measurements using EIT and EV1000 (PCA)