Journal of Clinical Monitoring and Computing
https://doi.org/10.1007/s10877-018-0124-5

LETTER TO THE EDITOR

Optimizing peripheral venous pressure waveforms in an awake pediatric patient by decreasing signal interference

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Received: 4 January 2018 / Accepted: 2 March 2018

Abstract
The purpose of this technological notes paper is to describe our institution's experience collecting peripheral venous pressure (PVP) waveforms using a standard peripheral intravenous catheter in an awake pediatric patient. PVP waveforms were collected from patients with hypertrophic pyloric stenosis. PVP measurements were obtained prospectively at two time points during the hospitalization: admission to emergency department and after bolus in emergency department. Data was collected from thirty-two patients. Interference in the PVP waveforms data collection was associated with the following: patient or device motion, system set-up error, type of IV catheter, and peripheral intravenous catheter location. PVP waveforms can be collected in an awake pediatric patient and adjuncts to decrease signal interference can be used to optimize data collection.

Keywords Peripheral venous pressure waveforms · Pediatrics

1 Introduction

In the pediatric population, dehydration is a common and sometimes life-threating diagnosis, but determining level of dehydration is still a difficult clinical task [1]. Vitals signs, urine output, and laboratory values are used to clinically assess and classify the degree of dehydration. However, these values may be difficult to obtain in the pediatric population, often requiring phlebotomy or catheterization. Scales have been developed to classify dehydration; however, they are not accurate and more precise predictors are still needed [2, 3]. Previous work in a young porcine model and in adults has demonstrated that fast fourier transformation (FFT) of a peripheral venous pressure (PVP) waveform correlated with volume status [4, 5].

In this pilot study of awake pediatric patients, we utilize PVP waveform analysis via a standard peripheral intravenous (PIV) catheter to study dehydration. The aim of this paper is to describe the technical aspects of PVP waveform data collection in awake pediatric patients and the lessons learned while optimizing the acquisition of accurate data to decrease interference.

2 Methods

After IRB approval, PVP waveforms were collected from patients with hypertrophic pyloric stenosis (HPS). A standard algorithm for fluid resuscitation was used based on the initial chloride and bicarbonate laboratory values [6].

Data was collected in a closed system via a 24-gauge Insyte-N Autoguard PIV catheter (Becton Dickinson Infusion Therapy Systems, Sandy, Utah, USA) connected to a T-connnector extension set (Baxter Interlink System, Deerfield, IL, USA) and then connected to a 48 in. arterial pressure tubing (Smiths Medical, Dublin, Ohio, USA). The arterial pressure tubing was connected to a Deltran II pressure transducer (ADInstruments, Colorado Springs, CO, USA) interfaced with a Powerlab data acquisition system (ADInstruments) (Fig. 1).

PVP waveforms were collected prospectively at two time points during the hospitalization: admission to the emergency department and in the emergency department after

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Published online: 06 March 2018

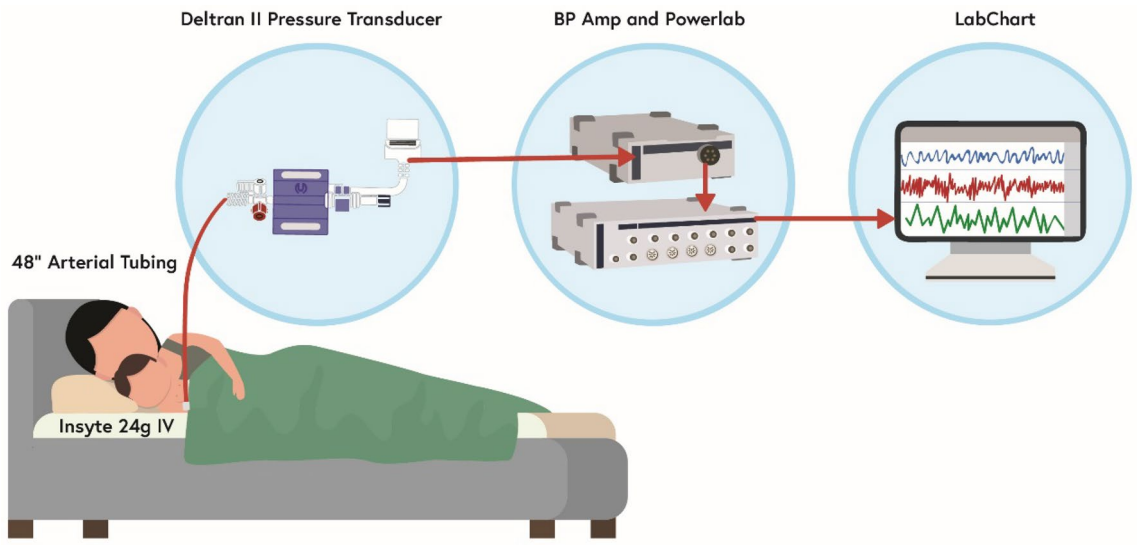

Fig. 1 Data acquisition setup including Insyte IV 48 in. arterial tubing, Deltran II pressure transducer, BP Amp, Powerlab, and Labchart

bolus in the emergency department. For each time point, the system was zeroed and PVP waveform data were collected for 10 min. Using LabChart (ADInsturments), figures were obtained at a 10:1 horizontal scaling and mmHg (y-axis) adjusted for demonstration purposes. The analysis routines deployed when extracting critical information from this data are able to work on signals that have a large variety of quality parameters. Hence, the assessment for determining if the signal quality was appropriate for further analysis was qualitative, but not part of a formal procedure.

3 Results

Data was collected from thirty-two patients. At time of enrollment, the mean weight was 3.9 kg and mean age was 37.3 days. 27/32 (84%) were male. A normal waveform is shown in the figure (Fig. 2).

Interference in data collection was associated with patient or device motion, system set-up error, type of PIV catheter, and PIV location. Movement artifacts were clearly visible in the acquired datasets, and post-processing of data ensured that only data acquired while no movement artifacts were present were utilized in the analysis and algorithm construction.

3.1 Motion causes PVP waveform changes

We found that the Deltran pressure transducer was sensitive to movements, caused by the patient and/or by external influences (Fig. 3). Patient movements interfering with PVP waveform collection included flexion and extension of arms or legs and crying with the most drastic changes occurring when the extremity with the PIV was moved. Other more subtle movements interfering with PVP waveforms from external influences included hitting the bed or adjusting the arterial tubing. Additionally, movements such as rocking or

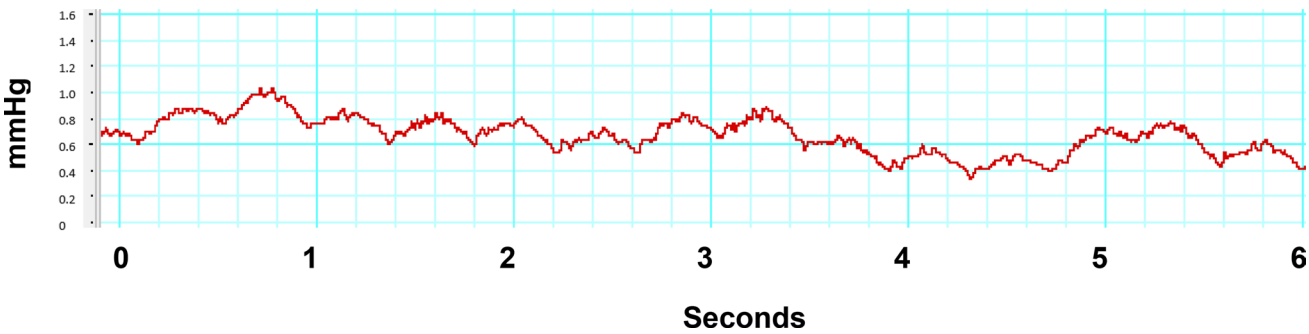

Fig. 2 Normal waveform from Labchart of the peripheral venous pressure measured in seconds

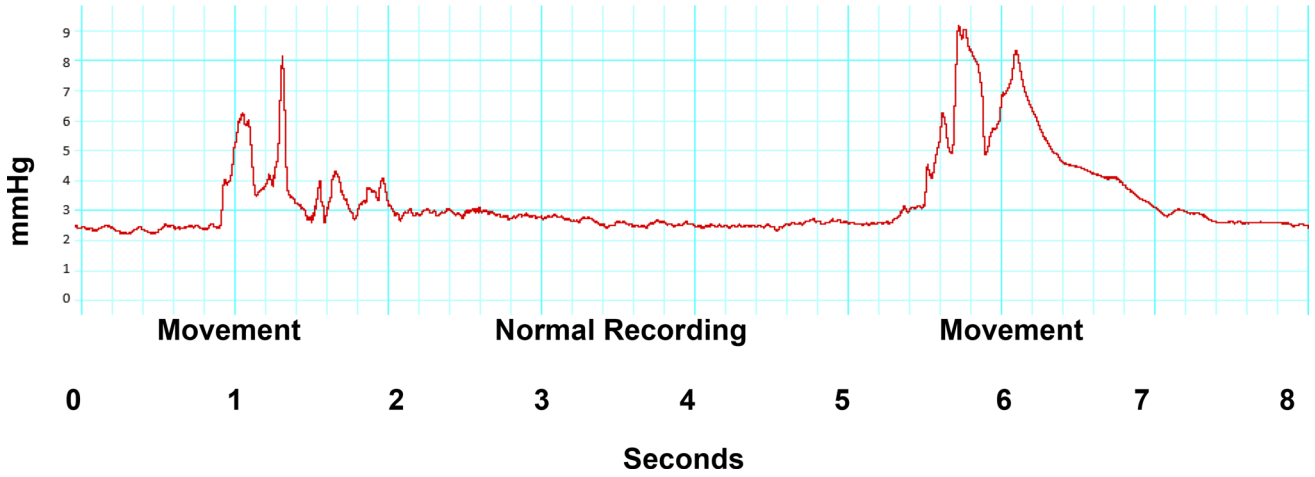

Fig. 3 Two separate patient movements separated by normal peripheral venous pressure waveform

tapping done while holding the child also interfered with the PVP waveform.

To overcome these barriers due to movement, sucrose water was placed in child's mouth and the child was wrapped in a warm blanket for comfort. Parents were asked to limit the amount of movement while holding the child during data collection. To aid in soothing of a breastfed child, another caretaker or nurse was asked to hold the child when collecting PVP waveforms. External influences interfering with the PVP waveforms were reduced by securely taping the Deltran transducer away from the patient on a hard non-mobile surface. Since the length of the arterial tubing was 48 in., it provided sufficient length away from the PIV insertion site for data collection.

3.2 Proper configuration, setup, and zeroing of system

The closed system pressure setup was critical for accurate data collection. Inaccurate waveforms were associated with kinking of the IV at the level of the skin. This scenario frequently occurred when the PIV was positioned over an area of flexion such as the wrist or antecubital fossa. To mitigate this issue, the extremity was splinted to limit flexion with arm splint and tape.

Air bubbles within the system or blood refluxed into the T connector also interfered with the PVP waveforms. If blood was left in the circuit without flushing, clots formed and the PVP waveforms were dampened. Air bubbles in the line also dampened the signal (Fig. 4). Proper system flushing prior to recording and running IV fluids through the Deltran transducer stop-cock when not obtaining recordings improved PVP waveform collection.

3.3 Type of intravenous catheter

Three of the thirty-two (9%) patients had a Nexiva (Beckon Dickinson Infusion Therapy Systems, Sandy, Utah, USA) closed IV catheter system which resulted in different PVP waveforms (Figs. 5, 6). Waveforms were able to be collected; however, PVP waveform appearance and the resulting FFT output between Nexiva group and our described set up were different. The Nexiva device has a built in stabilization platform with an IV extension at a 60° angle. If one wants to use this method, it is best to stick to one system since the PVP and FFT is impacted by the type of system.

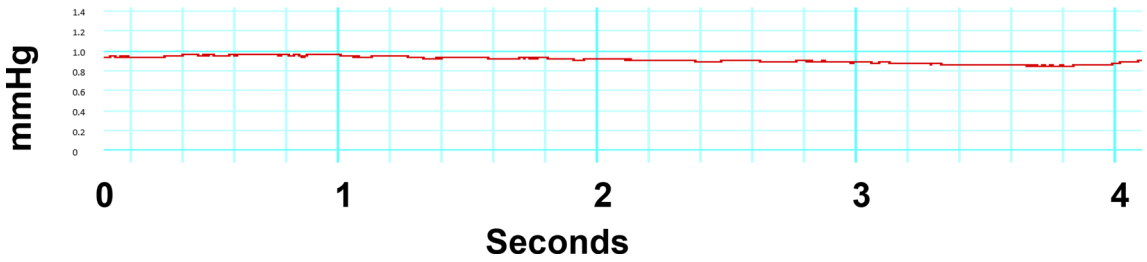

Fig. 4 Affect of air in line showing flattening of waveform

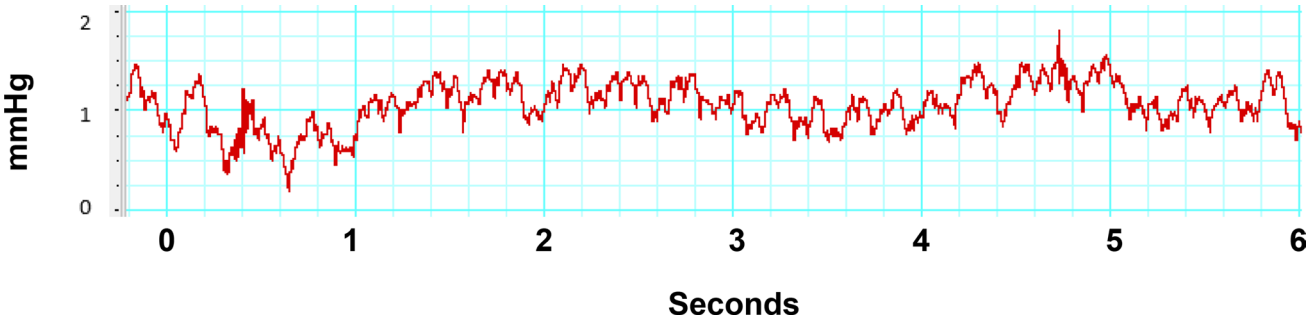

Fig. 5 Peripheral venous waveform obtained via Nexiva peripheral IV

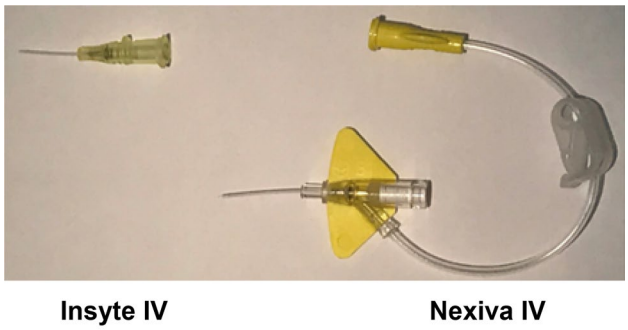

Fig. 6 Comparison of Insyte and Nexiva IV

3.4 Location of intravenous catheter

There was no difference in the PVP waveforms or FFT analysis output comparing upper and lower extremity location for the PIV.

One patient had a scalp IV which resulted in flattened PVP waveforms which could not be used for the waveform analysis (Fig. 7). We would recommend against scalp placement of the PIV.

4 Discussion

Our principle finding is that collection of PVP waveforms in an awake pediatric patient can be performed with accurate data acquisition. The closed system described does have limitations due to signal interference; however, adjuncts can be implemented to effectively improve PVP waveform collection in real-time.

Proper patient comfort is the most important aspect to decrease signal interference. The patient should be swaddled in a warm blanket, given sucrose water, held by someone other than the mother for breast-fed infants, and soothed prior to PVP waveform collection. To decrease the external interference due to movement of the Deltran transducer, the 48 in. arterial tubing allowed the Deltran transducer to be taped securely away from the patient and family.

Since the data was collected in a non-continuous fashion, flushing of the system is important prior to each data collection interval to flush residual blood and air from the line. PVP waveform collection was different based on the type of peripheral IV catheter (Insite vs. Nexiva), but waveforms could still be collected. Although our experience is limited to one patient, scalp IVs were not accurate for PVP waveform collection. We suggest that an upper or lower extremity PIV be placed for accurate waveform collection.

Results from this pilot study shows that PVP waveforms can be performed in an awake pediatric patient. As shown

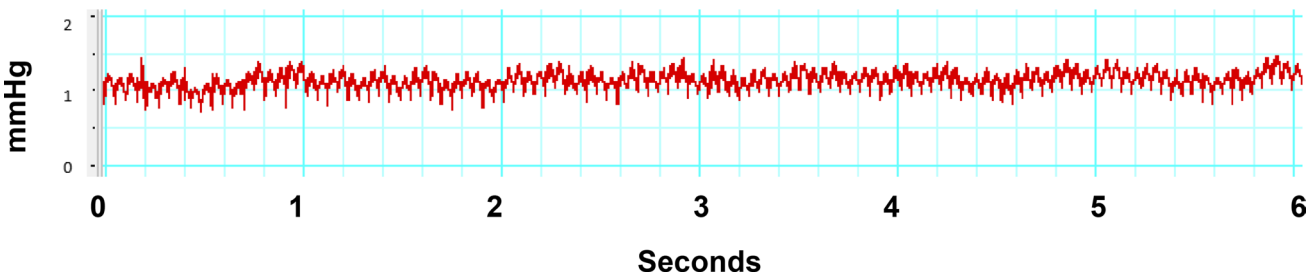

Fig. 7 Peripheral venous waveform obtained from scalp IV showing flattening and inaccurate waveform

by our device set-up, the ideal modality to determine volume status in the pediatric patients would be reproducible, non-invasive, user-independent, and provide a real-time assessment. These technical notes for PVP waveform collection in pediatric patients could significantly change the evaluation and management of volume status in children.

Acknowledgements Arkansas Children's Research Institute. The authors would like to thank Ms. Jacqueline Aguilar-Vega for help with illustrations.

Funding The funding for this project described was supported by the Translational Research Institute (TRI), Grant 1U54TR001629-01A1 through the National Center for Advancing Translational Sciences of the National Institutes of Health (NIH). The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH. Kevin W Sexton is supported by the UAMS Clinician Scientist Program. Jeffrey M Burford is supported by the Marion B. Lyon New Scientist Development Award. Morten O. Jensen is supported by the Arkansas Research Alliance.

Compliance with ethical standards

Conflict of interest This manuscript was written in compliance with ethical standards. The authors have no potential conflicts of interest.

Ethical approval The research involves data from human articipants and informed consent was obtained at time of study enrollment from each participant's care giver.

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