

# HOW TO DETECT HEMORRHAGING

WITH A SIMPLE DEVICE: CareTaker™

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## Origin of the pulse signal obtained by CareTaker

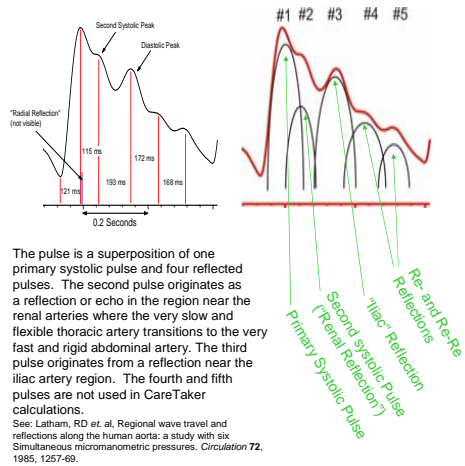
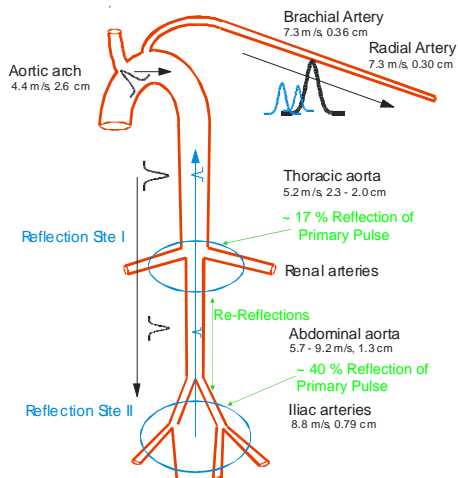


Diagram showing how the pulse structure originates in the Aorta



## CareTaker acquires the pulse signal using a low pressure air-filled cuff around a finger



P2/P1 tracks Systolic Blood Pressure, where P2 is the amplitude of the second systolic pulse relative pulse to the first systolic pulse.

T3 - T1 tracks the Pulse Pressure, where T3 is the arrival time of pulse 3 relative to pulse 1

P2/P1 - (T3 - T1) tracks the Diastolic pressure

Calculations are done on each pulse that is detected in real time

**CareTaker MONITORS AND RECORDS SYSTOLIC, DIASTOLIC, & MEAN BLOOD PRESSURES, INTER-BEAT INTERVAL, BREATHING RATE, AND T13 IN REAL TIME, BEAT BY BEAT.**

### The problem with pulse pressure

- The change in pulse pressure measured in mmHg is only about 10 mmHg for loss of > 1 liter blood loss (air pressure changes from weather, in contrast, can be several mmHg)

- Conventional BP monitors are incapable of measuring BP to accuracy better than +/- 10-12 mmHg. So, forget sphygmomanometers

- T13**, however, changes from about 300 msec to about 200 msec for loss of 1 liter with an uncertainty of about 10 msec.

- T13 correlates with hemorrhaging much more accurately than conventionally measured pulse pressure can.

• 15 healthy volunteers, a Lower Body Negative Pressure Chamber, an automatic blood pressure cuff, and a finapres

- average age: 24.4 years, SD = 3.0
- average height: 168.6 cm, SD=8.0
- average mass: 64.1 Kg, SD=9.1
- negative pressures of:
  - 10-20 mmHg corresponding to 0.4-0.5 liter
  - 20-40 mmHg corresponding to 0.5-1.0 liter
  - > 40 mmHg corresponding to > 1.0 liter
- Steps taken in all tests: -15, -30, -45, -60 mmHg

### Pulse Pressure during Central Blood Loss (Hypovolemia)

- Lower central blood volume reduces cardiac filling, which reduces stroke volume assuming compliance remains unchanged

- Both filling volume and stroke volume decrease during blood loss

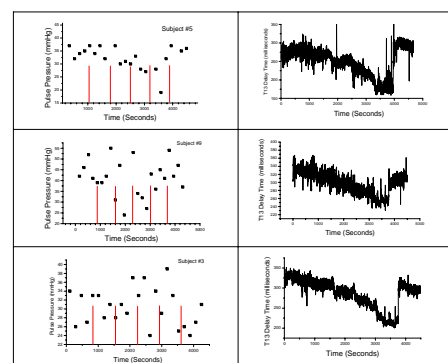
- Decrease in Pulse Pressure is expected during Central Blood Loss

- The Problem:
- **HOW TO MEASURE IT?**

- The Solution:
- Measure the time between the primary systolic pulse and the second reflected pulse in msec.

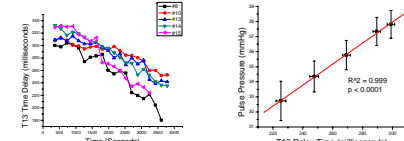
### THE INITIAL STUDY

## Using a lower body negative pressure chamber, CareTaker was compared to an automatic cuff



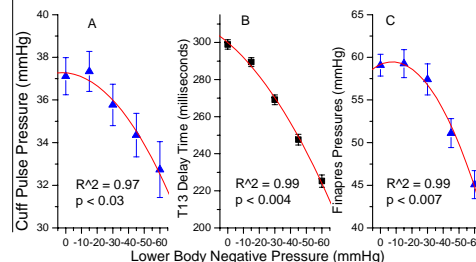
There is no useful information gained using a conventional BP device although one subject out of 15 (top) did show a little. The remaining subjects showed no correlation with pulse pressure as measured using an automated blood pressure cuff. The same was true for heart rate although many did have elevated heart rates especially near the end of the test.

### Example of composite values of T13 for other subjects

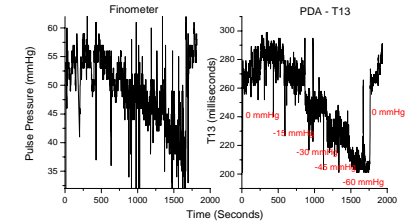


**All 15 subjects showed strong reduction in T13 during LBNP**

### Automated cuff (left), T13 (center), and finapres (right) measurements on all of the 15 subjects.



## Demonstration of CareTaker at USAISR



Temporal evolution of the arterial pulse pressure measured with a Finometer (left), and the T13 parameter (right) determined by the CareTaker system over the course of LBNP (58 y. old male). Wide band signal in T13 trace is not noise but due to respiratory sinus arrhythmia-induced pulse pressure modulations. Although not portable, the Finometer is the best instrument that is commercially available.

## CareTaker: A Multi Parameter Monitor

CareTaker can serve as a **Hemorrhagic Shock Monitor**. In all LBNP studies, T13 was observed to change from about 300 msec to about 200 msec for hemorrhaging of something near one liter. Additionally, CareTaker accurately tracks beat by beat blood pressure and measures heart rate as accurately as ECG. Because of the respiratory sinus arrhythmia, CareTaker can measure breathing rate and likely, *pulsus paradoxus* or inspiratory effort. CareTaker is the **ONLY** portable multi parameter monitor that has no wires or electrodes. CareTaker is the **ONLY** monitor that can detect and track hemorrhaging. CareTaker need only occupy the palm of the hand and the digit of one of the fingers to provide a full compliment of vital signs useful for battlefield casualty care and triage.

**Automatic Infusion pump systems** will require blood pressure measurements as near to continuous as possible. The fastest of conventional, automatic arm-cuff systems measure systolic blood pressure every one or two minutes, which takes a minimum of 15 seconds per measurement. This load on the arm is not pleasant after a short time. In the fastest conventional systems, the power requirements are high because the pumps are large and powered for high duty cycles. CareTaker measures blood pressure every heartbeat for over 12 hours on a cell phone battery and causes no discomfort. With Improvements in progress, CareTaker could extend this to about 100 hours using the same battery. Empirical has designed a system that combines a conventional arm cuff and the CareTaker. CareTaker is then calibrated against a conventional automatic cuff. Bluetooth communications are presently used for communication between the devices.

### Future version of CareTaker

- Palm sized system with finger cuff about 2" diameter and 1/2" in height
- On board analysis and data storage
- LCD for radio free use
- Bluetooth for uploading the data
- Virtual charts and notes for uploading
- Provides warnings of out-of-range parameters such as tachycardia
- Provides inputs to infusion systems
- 100 hour operation, continuous
- Three ounces in weight

### Acknowledgements

ONR SBIR Phase II with options, N0001404C0204, *Anti-Terrorism-Consequence Management and Recovery*, for a first responder health protection system  
 NHLBI SBIR Phase I, *Continuous BP Monitor for dialysis applications*, 1R43HL087476-01A1; 80 patients undergoing dialysis and 20 patients with arterial and aortic catheters  
 OTTC/CCAT at California State University, San Bernardino, building of multiple CareTaker prototypes  
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