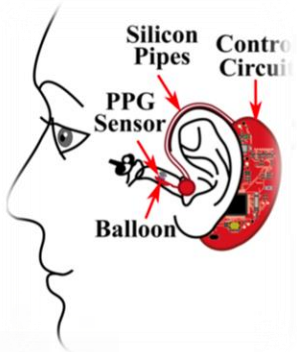


eBP: A Wearable System For Frequent and Comfortable Blood Pressure Monitoring From User's Ear

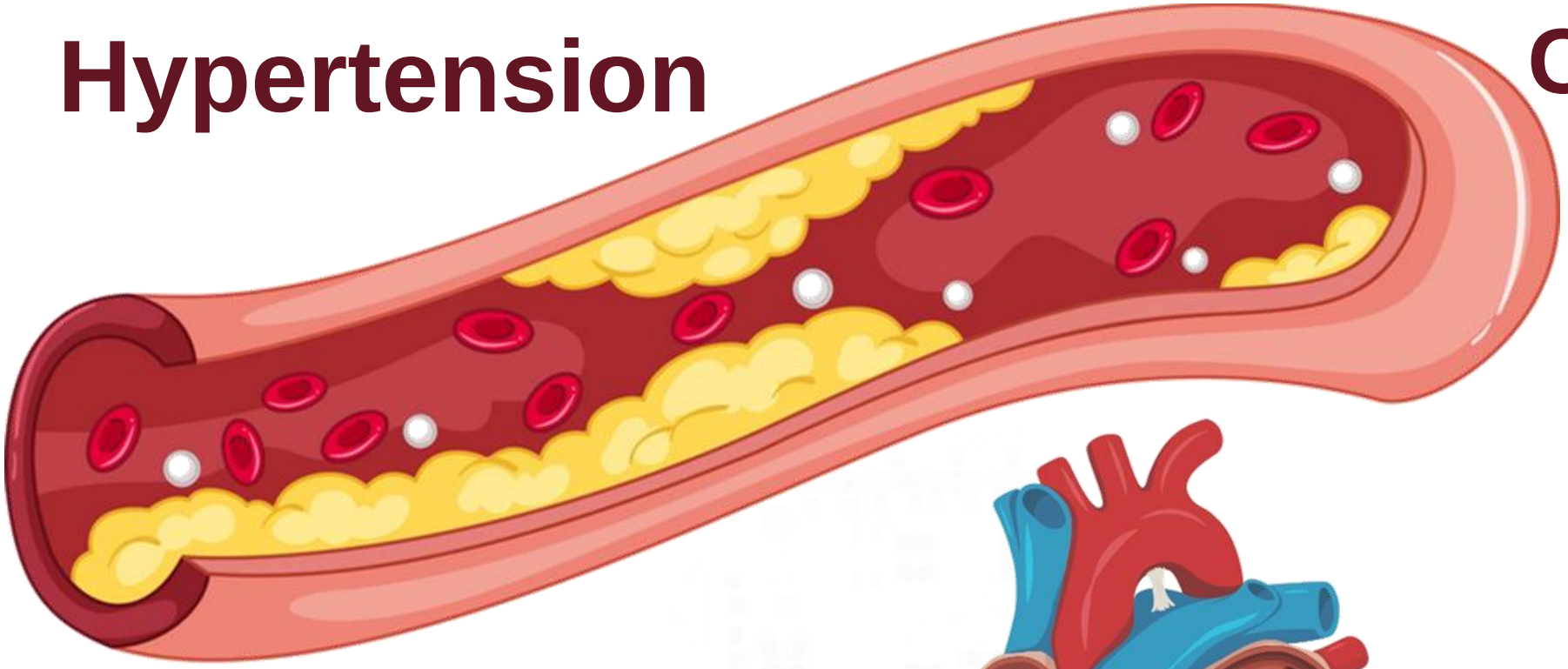
Nam Bui[+], Nhat Pham[+], Jessica Barnitz[+], Zhanan Zou[+],

Phuc Nguyen[+], Hoang Truong[+], Taeho Kim[+], Nicholas Farrow[+], Anh Nguyen[+],

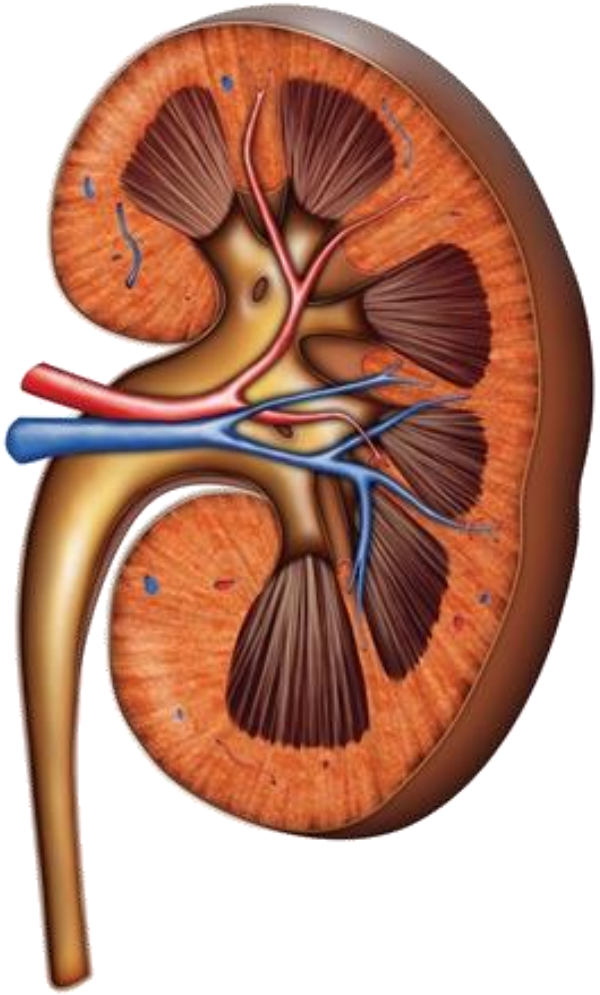
Jianliang Xiao[+], Robin Deterding[+], Thang Dinh* and Tam Vu[+].

[+]University of Colorado, *Virginia Commonwealth University,

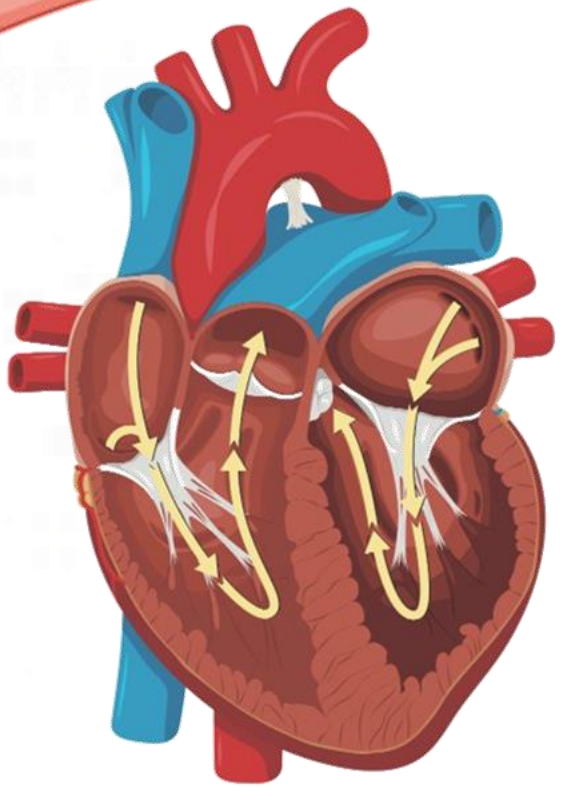
Hypertension



Chronic Kidney Disease



Heart Failure
Stroke



Blood Pressure is the key vital sign for many diagnosis.

Arm-cuff BP monitoring

Wrist-cuff BP monitoring

Common BP monitoring devices.

Hypertension – Ambulatory Blood Pressure Monitoring (24 hours)

https://www.sciencesource.com

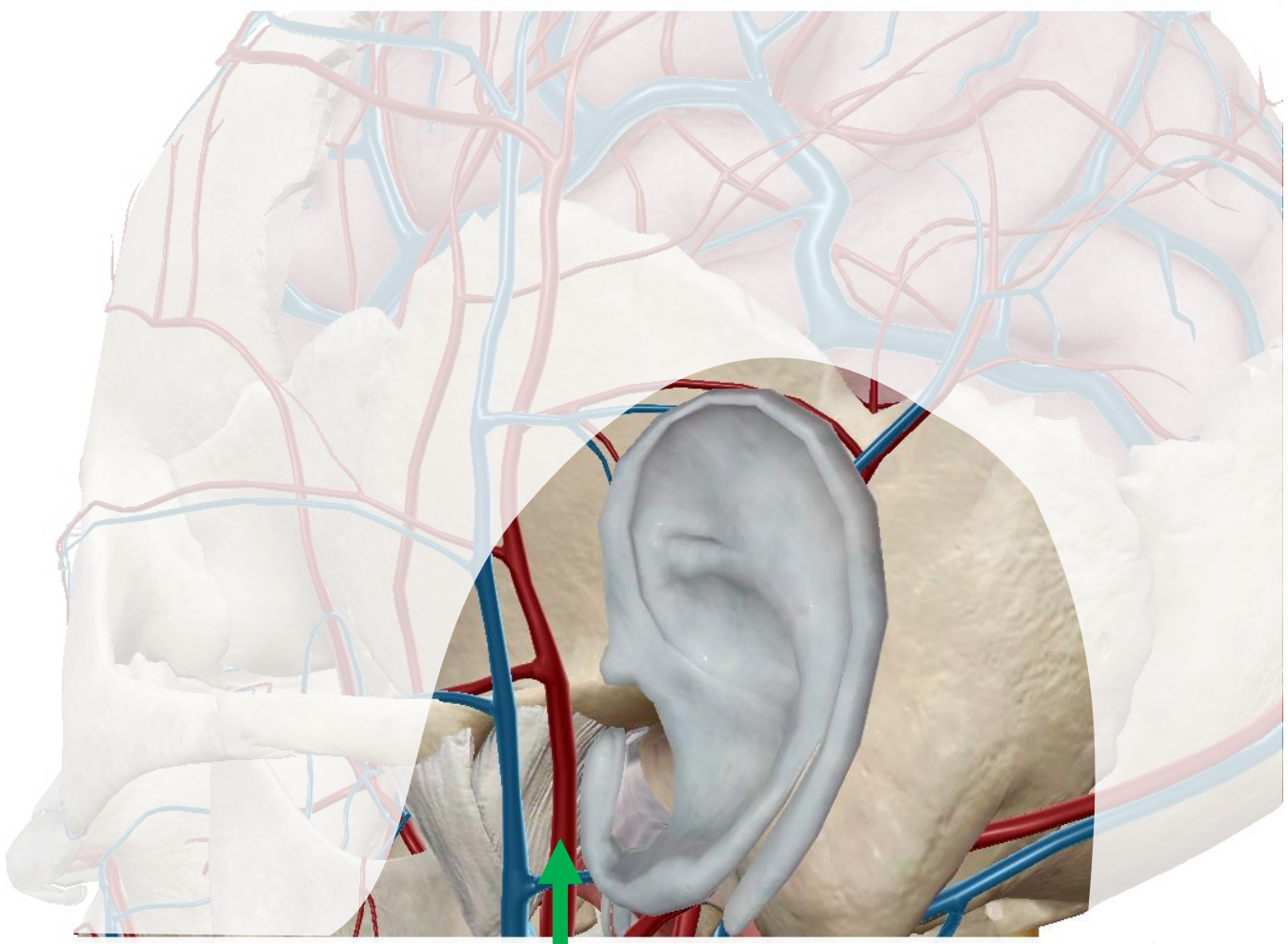
https://www.sciencesource.com

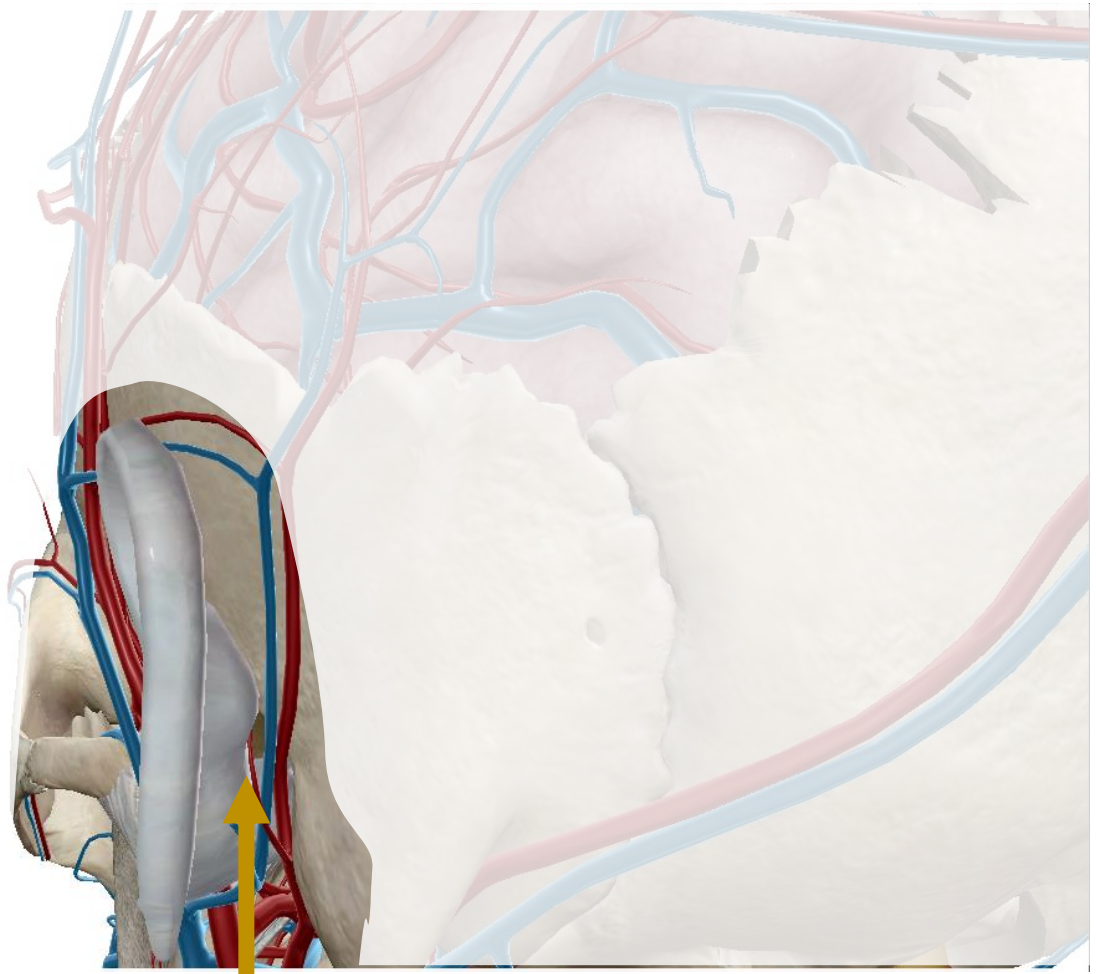
https://www.ttpventus.com

- Convenient
- Unobtrusive.
- Frequent & long-term usage.

eBP: In-ear Blood Pressure Monitoring System

Analysis of arterial system around the ear

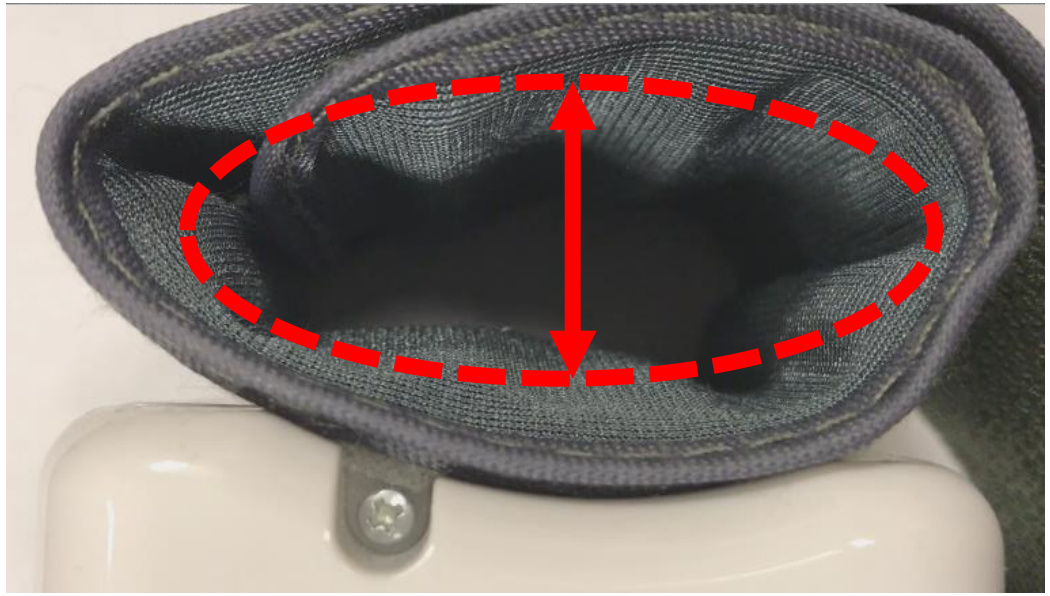


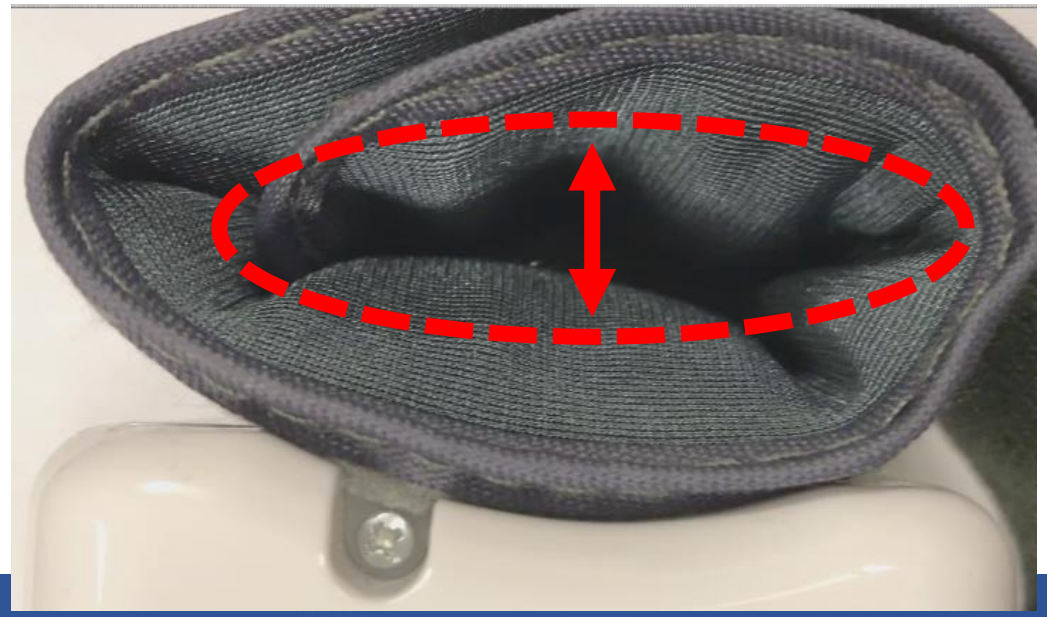


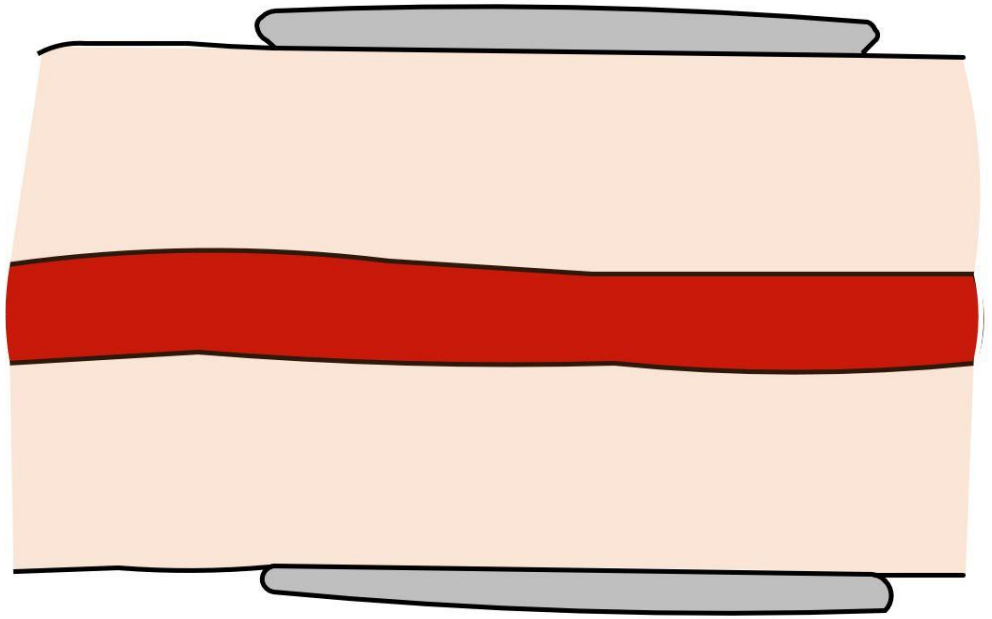
Superficial Temporal Artery

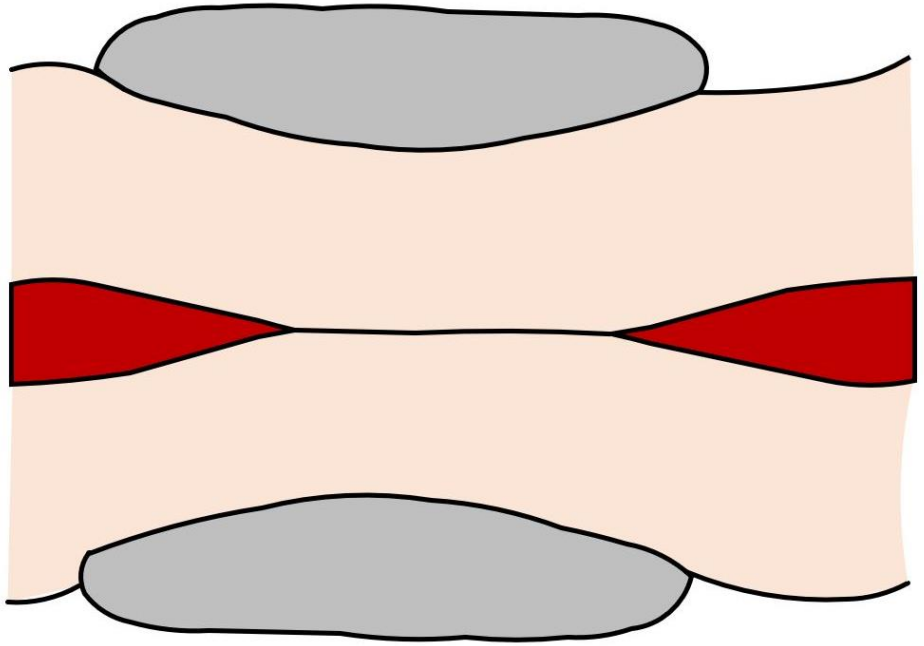
Posterior Auricular Artery

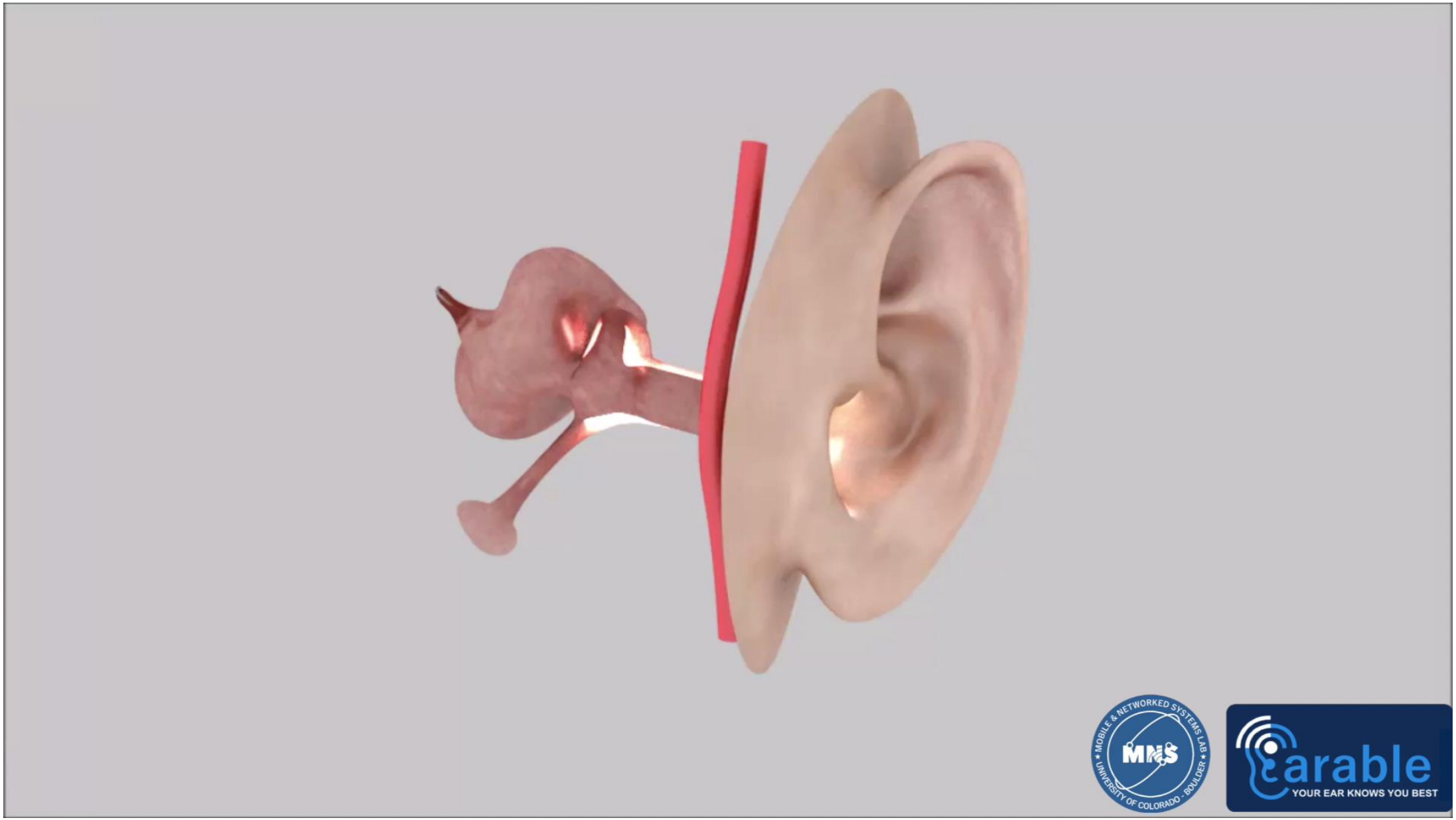
Fundamentals of Arm/Wrist Cuff Mechanism





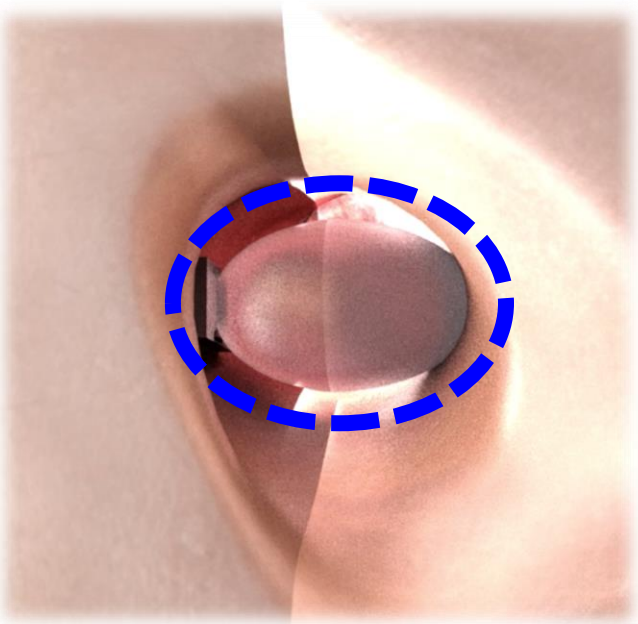


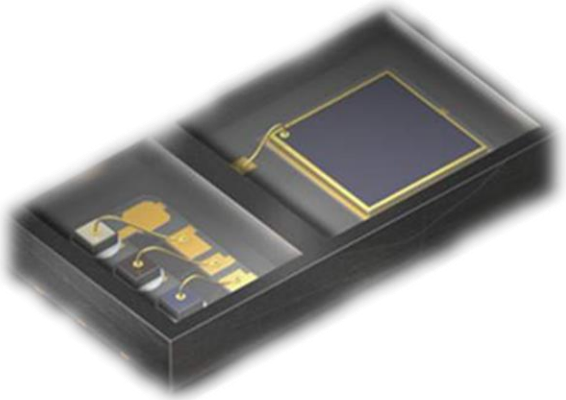


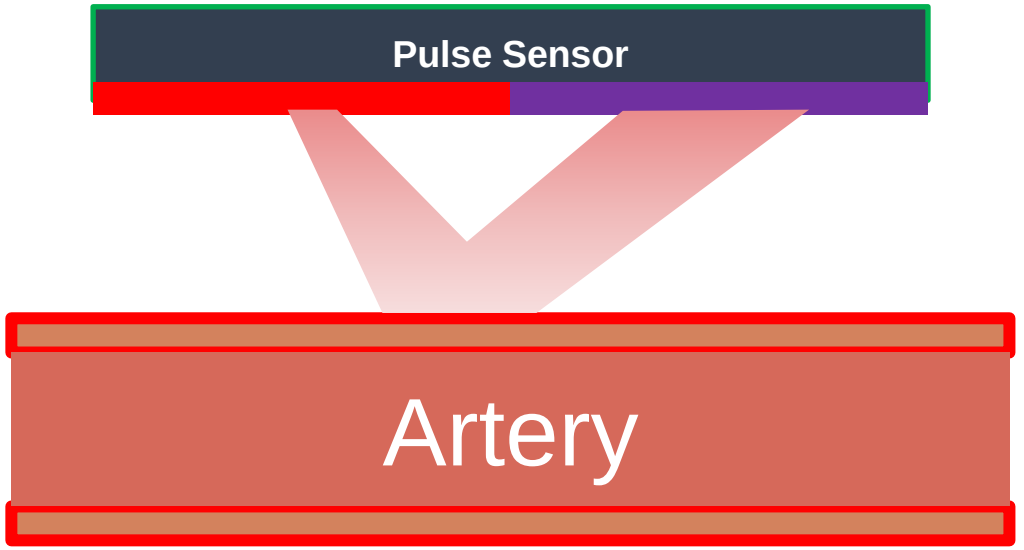


Introduce In-ear Blood Pressure Monitoring

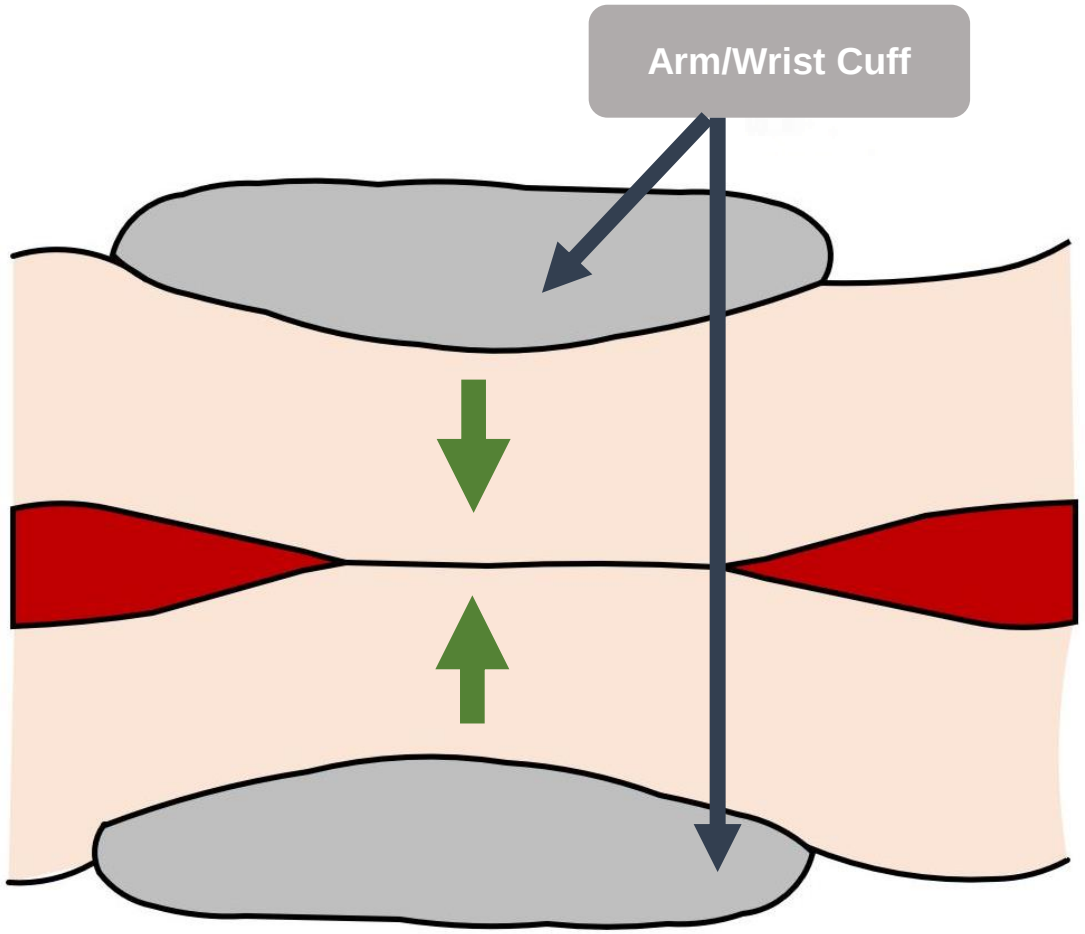
Photoplethysmogram (PPG) Pulse Sensing



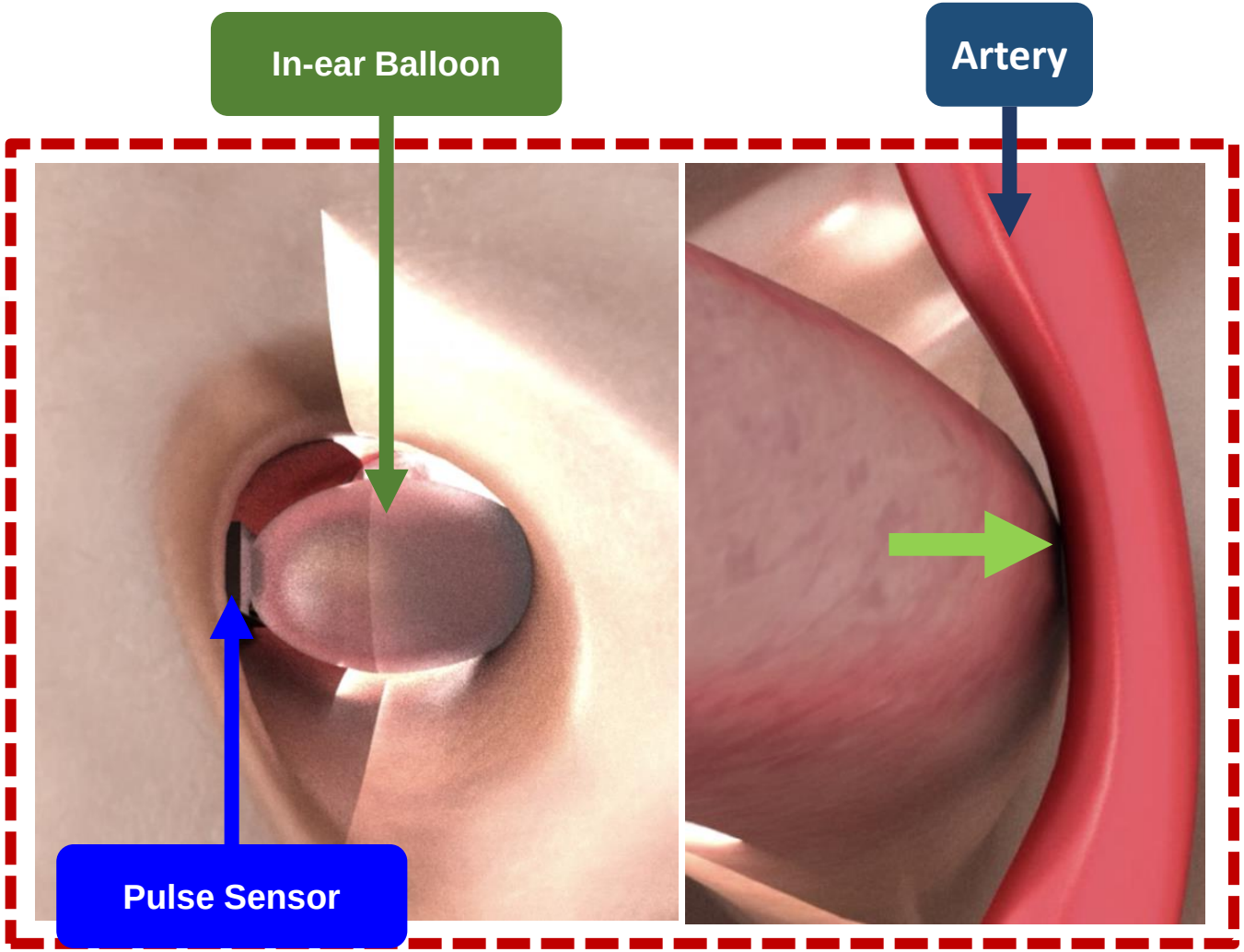




Challenge: Arteries inside the ear cannot be completely blocked by the balloon.

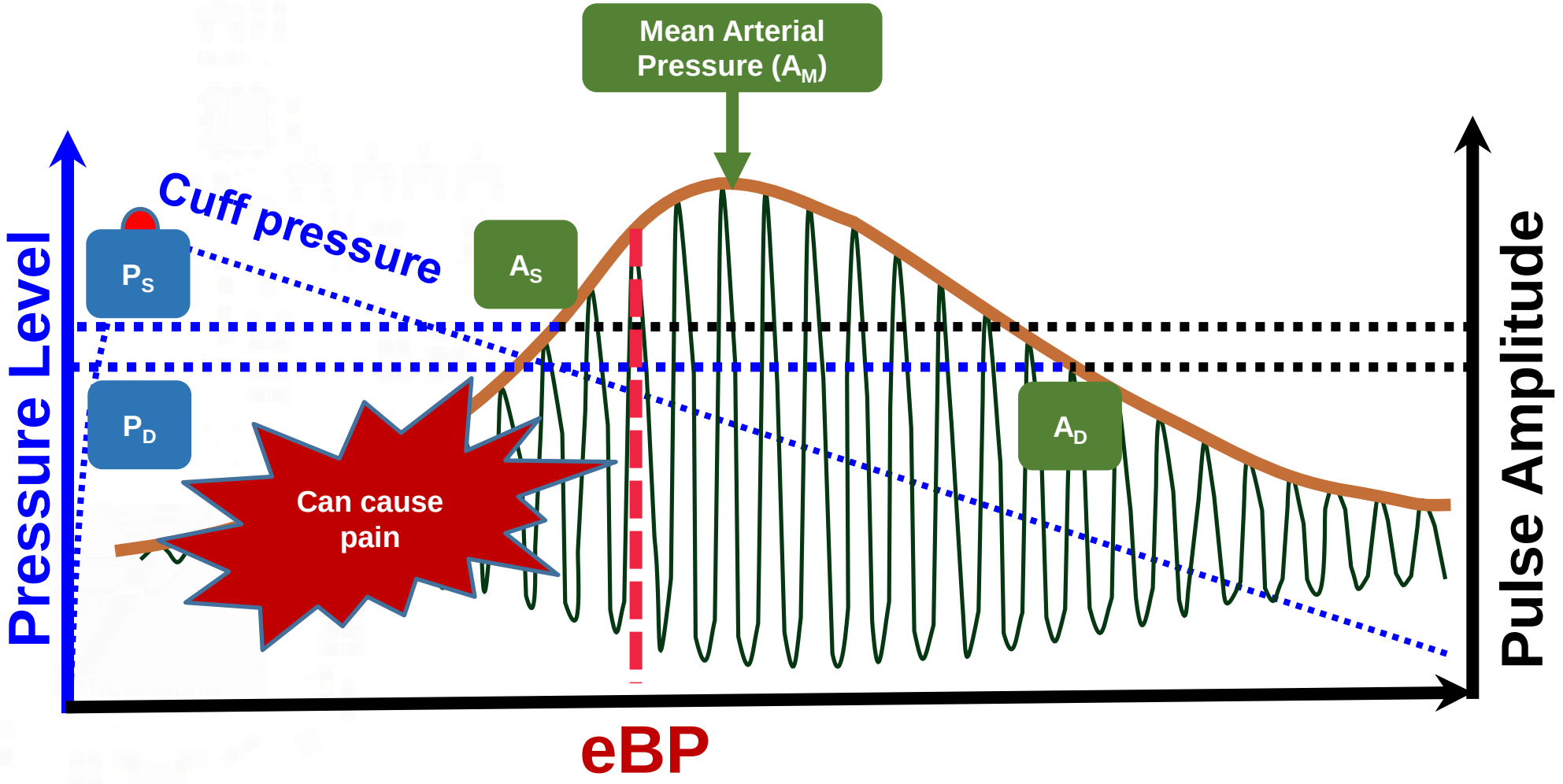


Conventional Cuff device

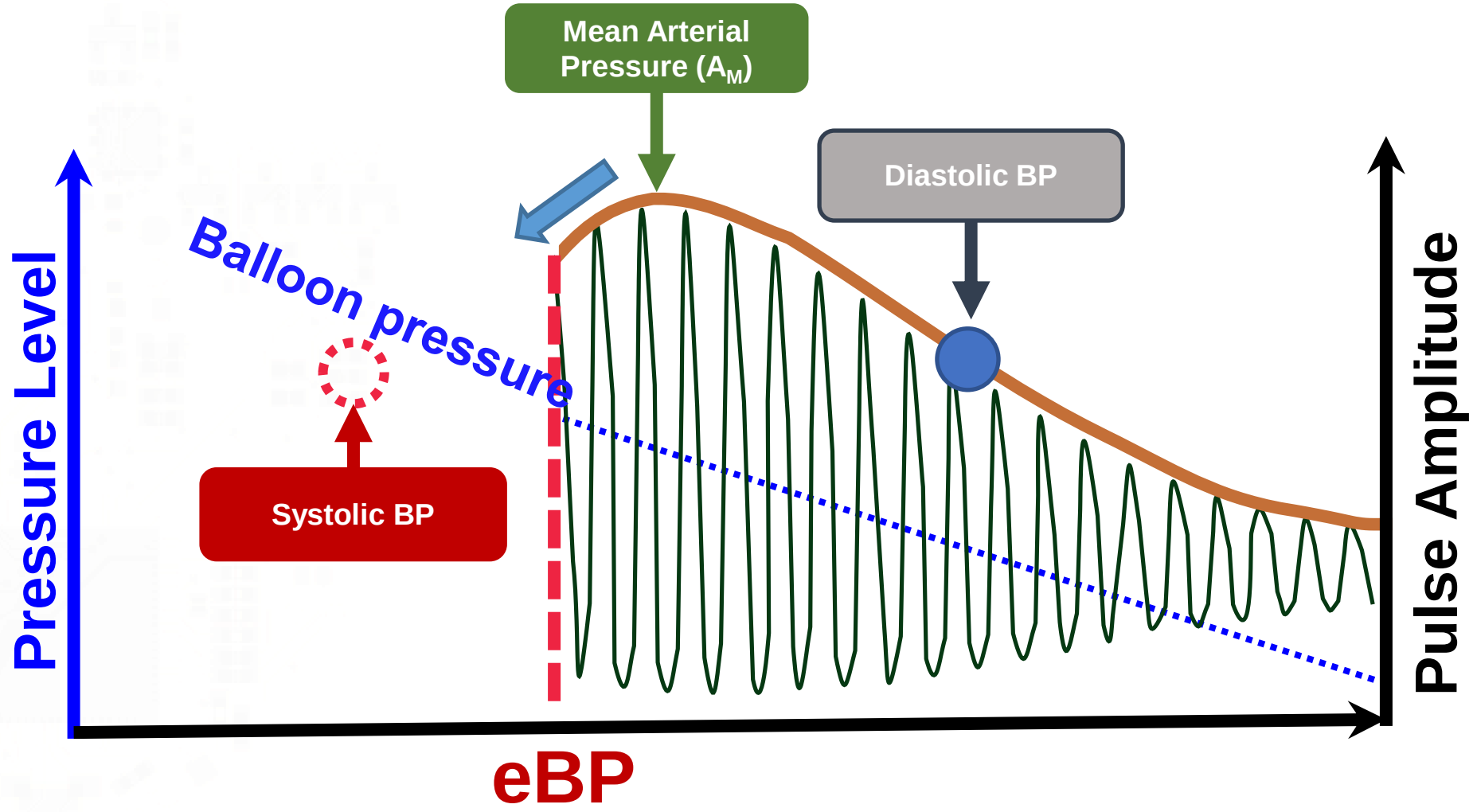


eBP

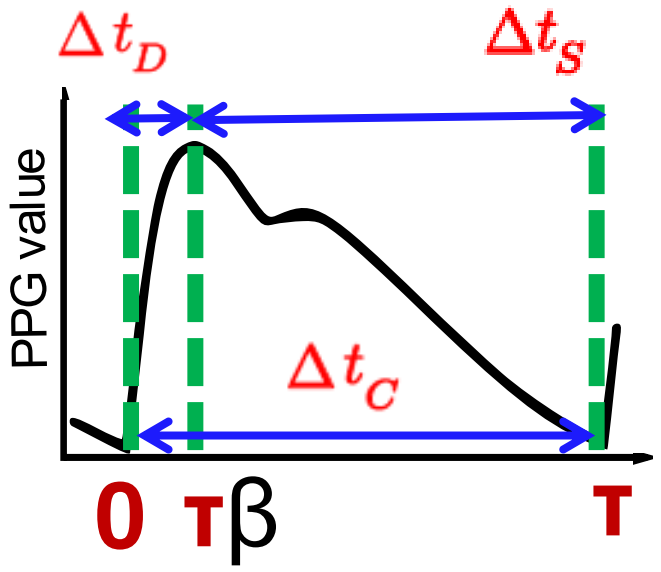
Oscillometric BP measurement



In-ear blood pressure measurement model



Relational equation between the MAP, systolic, diastolic BP



❑**The Mean Arterial Pressure (MAP)** : is the **average value of BP in one cycle**.

$$P_{MAP} = \frac{1}{\tau}\int_0^{\tau} P(t)dt$$

- ❑ Assuming:
  - ❑ Pulse duration [0, τ]
  - ❑ $\beta = \Delta t_S/\Delta t_C$ is the systolic fraction.
- ❑ The **systole is in the interval (0, $\tau\beta$)** and **diastole is from $(\tau\beta, \tau)$**.

$$P_{MAP} = \frac{1}{\tau}\int_0^{\tau\beta} P(t)dt + \frac{1}{\tau}\int_{\beta}^{\tau\beta} P(t)dt = \beta\left[\frac{1}{\beta\tau}\int_0^{\tau\beta} P(t)dt\right] + (1-\beta)\left[\frac{1}{(1-\beta)\tau}\int_{\tau\beta}^{\tau} P(t)dt\right]$$

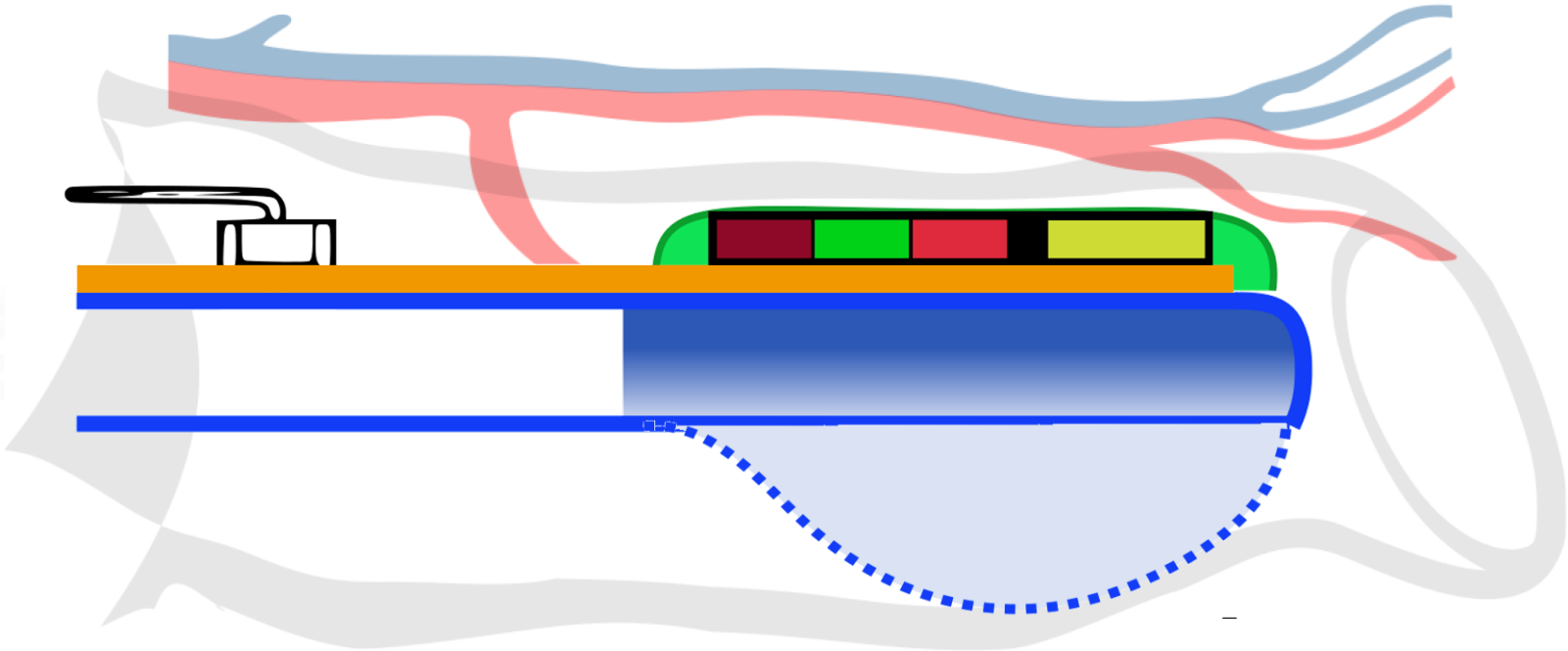
P_S P_D

$$P_M = \beta P_S + (1-\beta)P_D$$

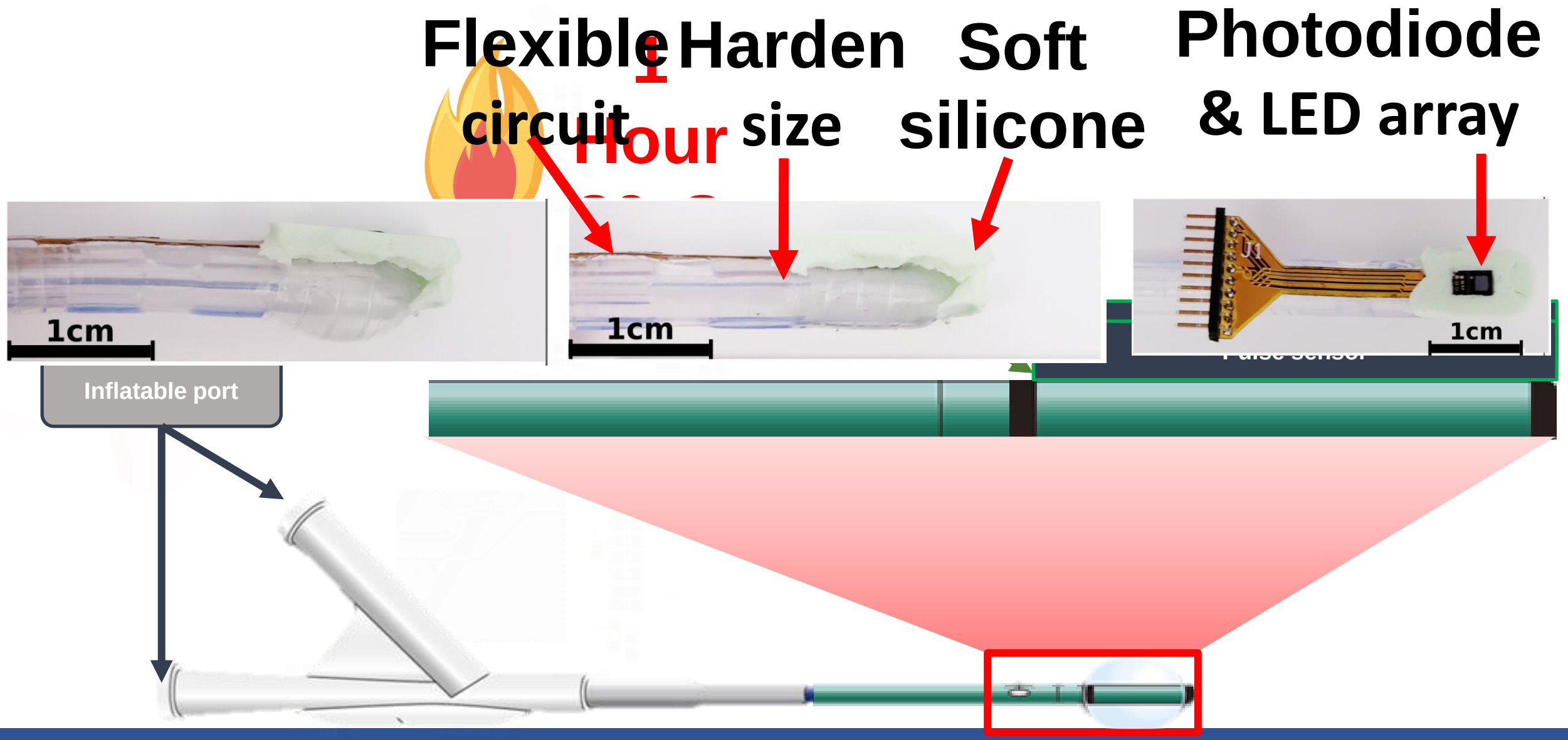
$$\beta = \Delta t_S/\Delta t_C$$

Challenge: In-ear balloon design.

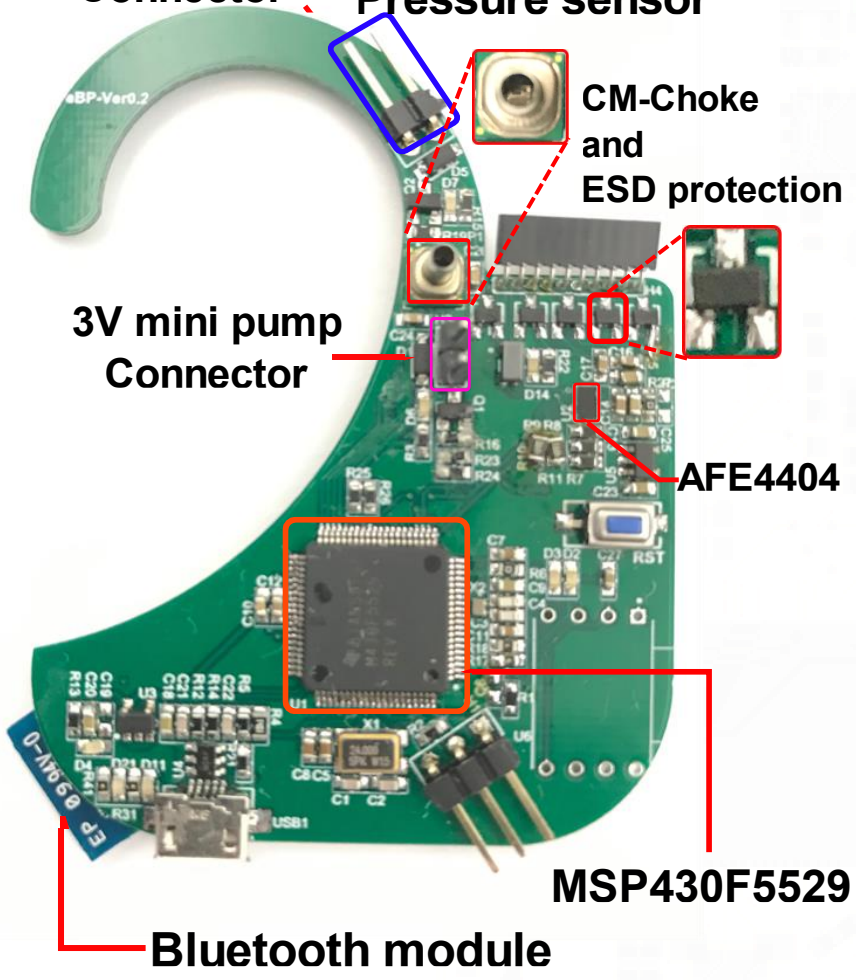
- **Medical Safe.**
- **Bio-compatible.**
- **User's comfort.**
- **Be able to attach Pulse sensor.**
- **Fit inside the ear.**
- **Be Inflatable inside the ear.**



Making the balloon



Prototype


Solenoid valve Connector
Pressure sensor
CM-Choke and ESD protection
3V mini pump Connector
AFE4404
MSP430F5529
Bluetooth module


10-pin-to-10-pin cable
In-ear pulse sensor
Solenoid valve
Catheter balloon

Experiment

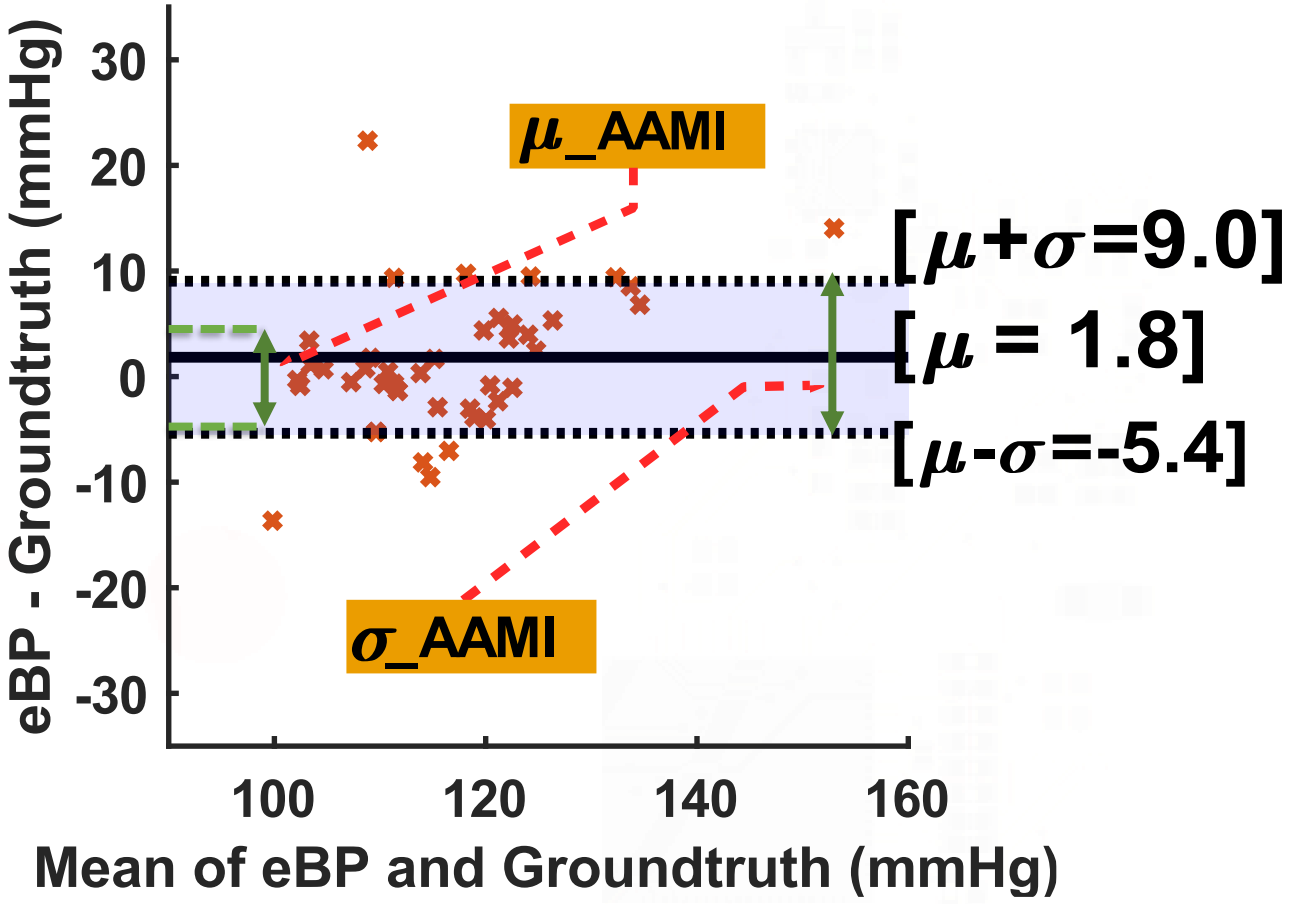
Demographic data of study population	
Age (years)	18 - 35 years old
Blood Pressure	Systolic: 93-146 , Diastolic: 53-113
Gender Ratio	Male: 24, Female: 11

Ground truth device: KonQuest KBP-2704A

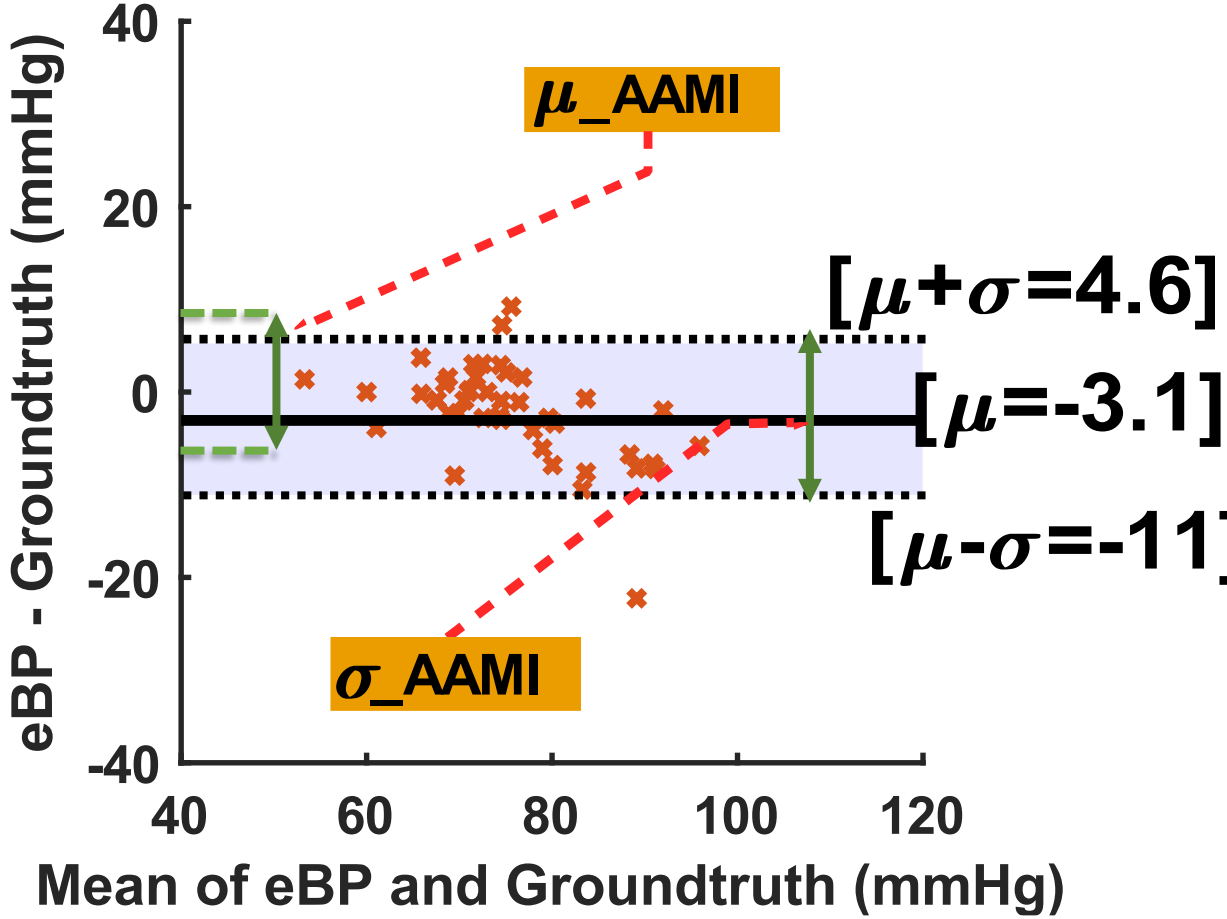
Calibration: Polynomial regression model on the data of 5 subjects.

Result

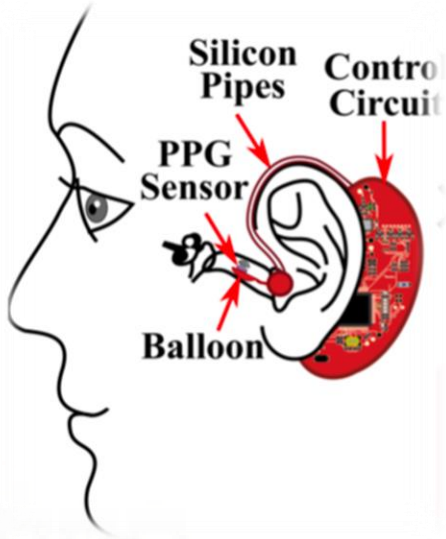
Association for the Advancement of Medical Instrumentation



Systolic BP

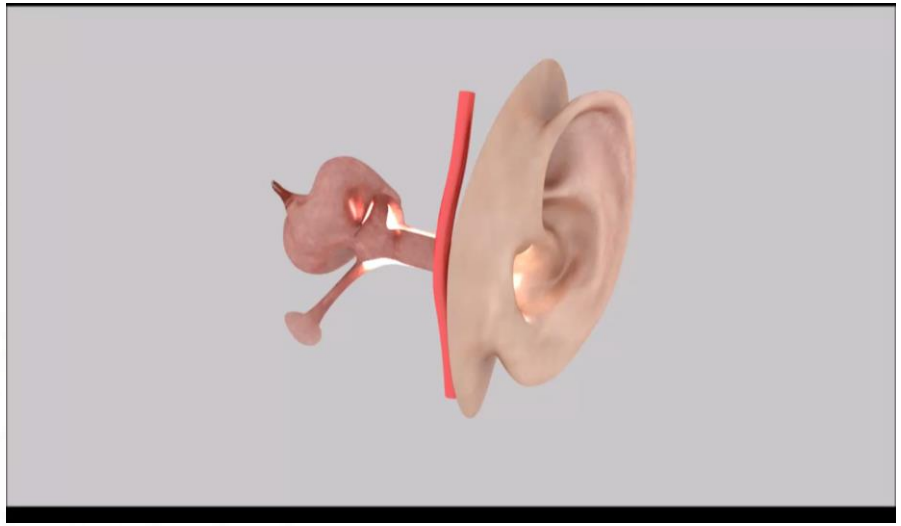


Diastolic BP



Integrated to ***earphone or a hearing aid*** for frequently measuring BP

Improve the ***algorithm of existing cuff*** devices.



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