Department of Biomedical Engineering

VI Semester

CBM 370 - Wearable Devices

Unit- 5 APPLICATIONS OF WEARABLE SYSTEMS

5.3 Hospital patients

Wearable systems have become increasingly important in healthcare, particularly for hospital patients. These systems offer continuous monitoring, data collection, and early intervention capabilities that improve patient outcomes and optimize hospital operations.

- By means of WDs, it is possible to monitor vital signs (heart/pulse rate, blood pressure, respiratory rate, temperature), glucose levels, body position, and activity, among other things. This type of technology allows for non-invasive frequent measurements, or continuous monitoring.
- Wearables can help reduce medical errors, minimize the risk of adverse events, and save both time and costs.

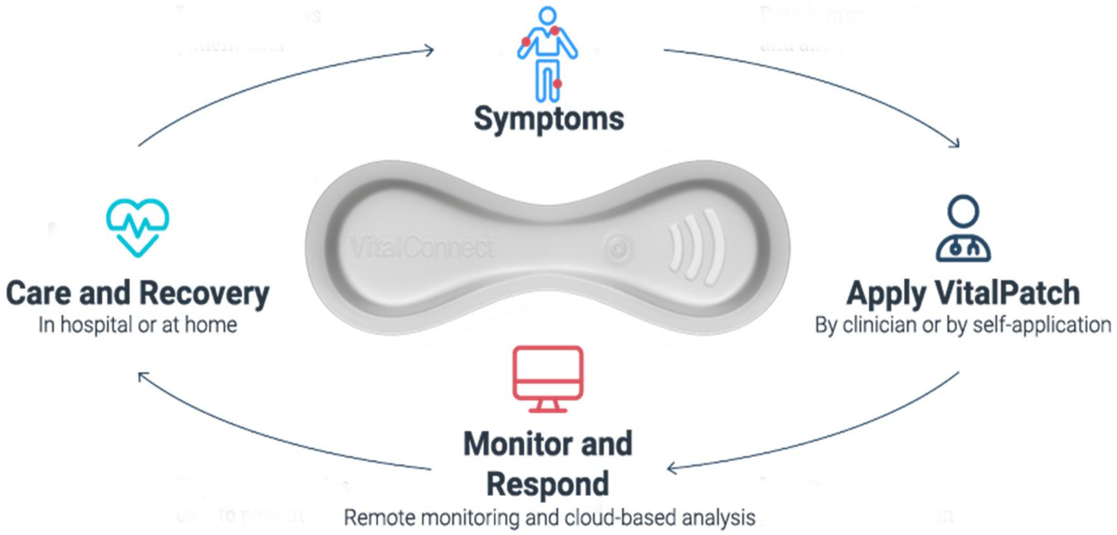
I. Cardiac function:

Techniques used in WDs to measure cardiac function include

- Electrocardiography (ECG),
- photoplethysmography (PPG),
- seismocardiography (SCG), and
- phonocardiography (PCG).

1. Electrocardiography:

ECG consists in the non-invasive recording of the electrical activity of the heart and is performed by placing electrodes to detect abnormalities. The parameters that are usually extracted are heart rate (HR), HR variability (HRV), and the waveforms of the P-QRS-T complex. Changing heart rhythms can only be detected in long-term recordings with continuous ECG (cECG), and a possible alternative to traditional equipment is represented by patch ECG devices. Such devices are in fact unobtrusive, wire free, and able to record from weeks to months. Wearable ECG devices could be in the form of an 'on-body patch' or a contact-less sensor as a smart watch, 'textile-base' vest, or capacitive sensors integrated within patients' stretchers, beds, and wheelchairs.



The VitalPatch (as shown in figure) , a wearable sensor, is applied either by a clinician or by the patient themselves. The VitalPatch facilitates remote monitoring and cloud-based analysis of the patient's physiological data. This allows healthcare providers to track the patient's condition and respond appropriately.

2. Photoplethysmography (PPG):

- PPG is an optical technique utilized to detect changes in blood flow volume within a peripheral vascular bed. PPG measurement sites include fingertip, wrist (as in smartwatches and personal fitness trackers, or PFTs), arm, earlobe, esophagus, forehead, thigh, leg, and ankle.
- The two main parameters measured by PPG are PR, serving as a surrogate for HR and SpO2.
- Early accuracy studies conducted in ICU demonstrated that it is feasible to use PPG-based fitness trackers to assess PR.

❖ A wrist-worn commercial PFT (Fitbit Charge HR, Fitbit, San Francisco, California, USA) was employed in 50 stable ICU patients for detection of PR, activity, and sleep.

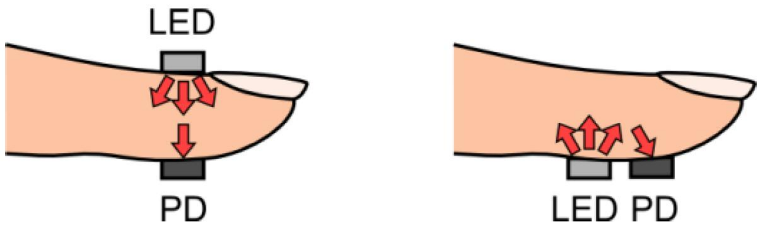


Figure 5.3.2: Light-emitting diode (LED) and photodetector (PD) placement for transmission- and reflectance-mode photoplethysmography (PPG).

❖ The wearable PPG has two modes—transmission and reflectance—as shown in **Figure 5.3.2**. In transmission mode, the light transmitted through the medium is detected by a PD opposite the LED source, while in reflectance mode, the PD detects light that is back-scattered or reflected from tissue, bone and/or blood vessels.

3. Seismocardiography:

❖ SCG is the process of measuring the vibrations of the body, specifically those occurring in the thoracic region, which are induced by the contractions of the heart and the ejection of blood from the ventricles.

❖ It is possible to record a seismocardiogram by placing an Inertial Measurement Unit (IMU) on the chest of a person. The parameters that can be obtained from SCG are HR and HRV.

4. Phonocardiography (PCG):

❖ Acoustic sensors, such as microphones and piezoresistive sensors, are used to detect heart sounds in PCG. Wearables equipped with such sensors are capable of detecting heart sounds like S1 (closure of atrioventricular valves) and S2 (closure of semilunar valves), and possibly capture additional sounds

(S3, S4) or even murmurs. PCG and ECG can be used in combination: this technique is called electro-phonocardiography and can be used in wearables due to its non-invasiveness.

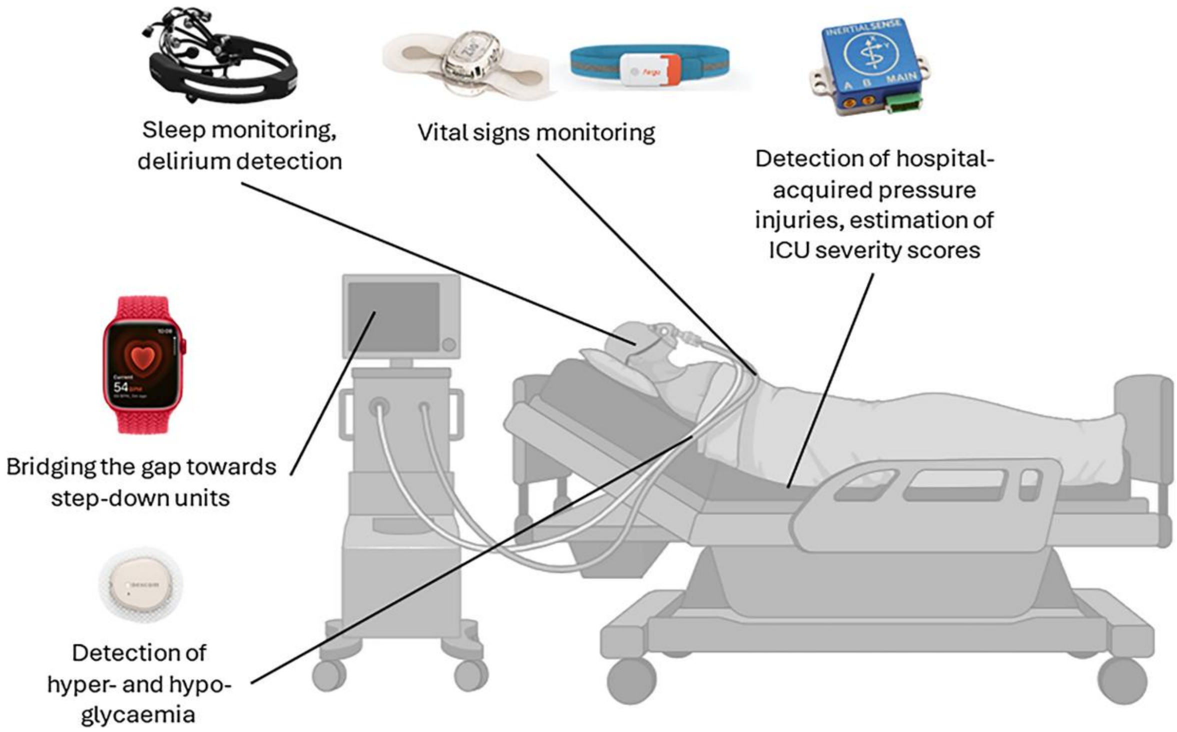


Figure 5.3.3 Use of wearable devices in the ICU

II. Arterial blood pressure measurement:

Arterial blood pressure (ABP) is another parameter of interest in cardiac monitoring. ABP can now be measured noninvasively by wearable cuff less devices. Cuff less methods to perform this meassrement exploit either the pulse arrival time (PAT) or the pulse transit time (PTT). PAT is the time that the pulse waveform takes to go from the heart to a distal site, and is obtained by computing the temporal difference between the R-peak in the ECG signal or the beat detected in the SCG signal and the peak of the PPG waveform. A **control system** uses the PPG signal to adjust the pressure in the finger cuff in real-time to **keep the finger's arterial volume constant**.

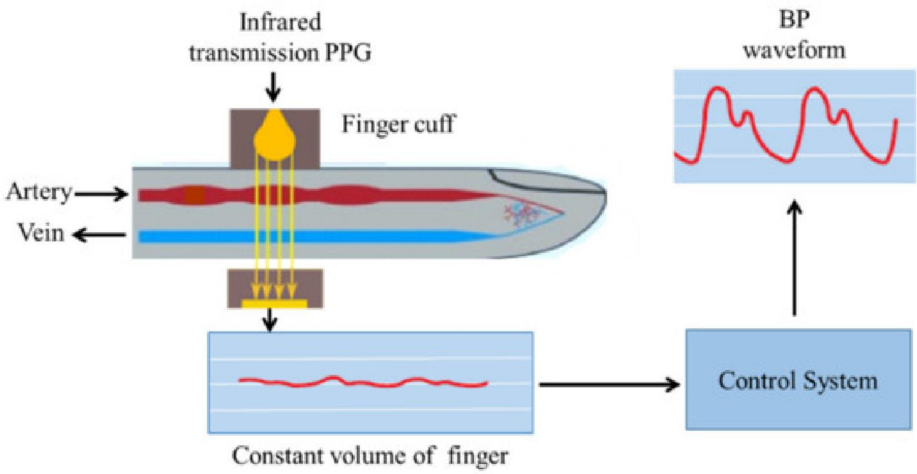


Figure 5.3.4. Noninvasive BP waveform estimation using the vascular unloading technique.

[Figure: www. https://www.mdpi.com/1424-8220/22/10/3953]

III. Respiratory waveforms derived from cardiac signal:

- The ECG and the PPG waveforms allow to derive the RR. Chest movements affecting the electrodes cause morphological changes to the shape of the QRS complex of the ECG.
- Respiratory waveforms can be **derived from cardiac signals** such as ECG (electrocardiogram) or PPG (photoplethysmogram) by exploiting the **physiological influence of respiration on the cardiovascular system**. This process is valuable for applications where direct respiratory measurements (like from a chest belt or spirometer) are not available.

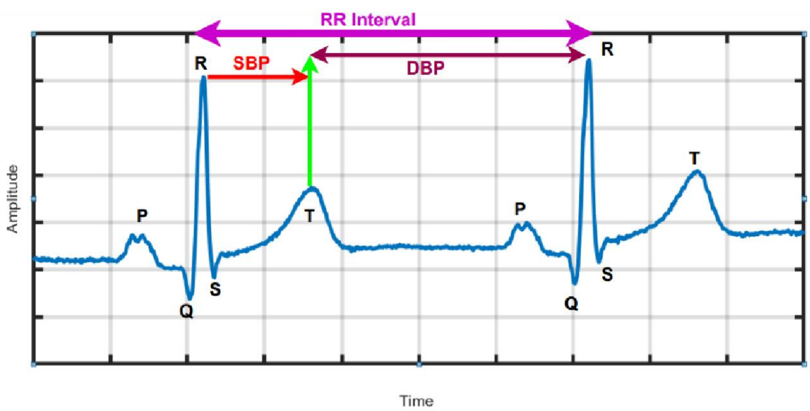
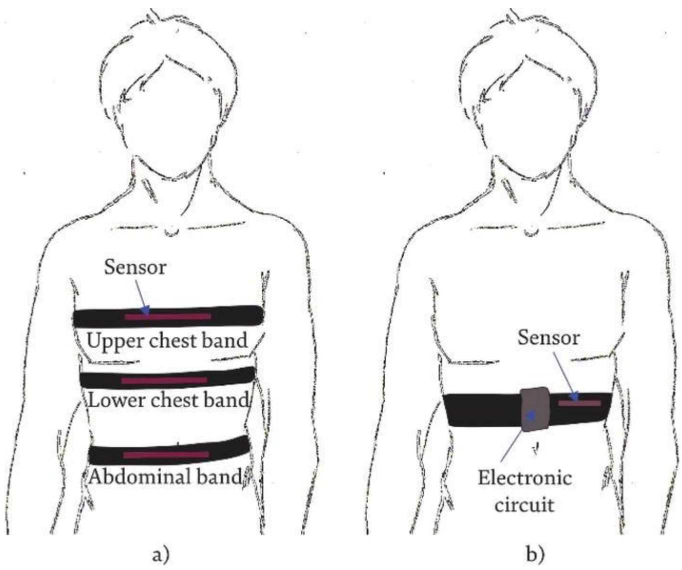


Figure: Automated Detection of Hypertension Using Physiological Signals

III. Chest wall movements:

- Chest wall movements can be detected by several different sensors, which can be based on changes in resistance, capacitance, inductance, impedance, inertial measurements, light, sound.
- From chest wall movements, it is also possible to derive RR with good accuracy, and there is increasing research interest in the estimation of tidal volume (V_T) from data that can be acquired with WDs.
- Piezoresistive sensors allow detection of chest wall movements by changes in resistance, and several garments are based on this technology.
- Capacitive sensors measure the capacitance between two electrodes. If the two electrodes are placed on the chest wall, the latter acts as a dielectric material, and the variations in capacitance will correlate with RR.
- Respiratory inductance plethysmography (RIP) is based on changes in inductance; two transducer bands are placed around the chest wall to monitor excursions of the thorax and abdomen.
- Impedance pneumography consists in the recording of the bioimpedance of the chest wall for the indirect measurement of respiration, using superficial electrodes.
- IMUs can also be used to monitor respiratory parameters like RR and VT. Generally, one or two IMUs are placed on the chest wall.



***Ref.**: https://www.intechopen.com/chapters/66828*

IV. Brain Activity:

- Electroencephalography (EEG) is a technique designed to monitor brain activity by recording the electrical signals non-invasively and is being increasingly used to implement brain–computer interfaces.
- The biopotentials are detected using surface electrodes placed on the scalp.
- EEG detects wavelengths < 80 Hz, and the waves that are generated by brain activity are classified as delta (1–4 Hz), theta (4–8 Hz), alpha (8–12 Hz), beta (12–25 Hz), and gamma (> 25 Hz).
- Wireless transmitters in EEG systems play a crucial role in enabling the portability and flexibility of brain activity monitoring.
- These transmitters are embedded within the EEG system and are responsible for capturing the electrical signals generated by neurons firing in the brain.
- Once these signals are detected by electrodes placed on the scalp, the transmitter converts the analog electrical signals into digital data and sends them wirelessly, via Bluetooth or Wi-Fi to a nearby device such as a computer, smartphone, or tablet for real-time analysis.

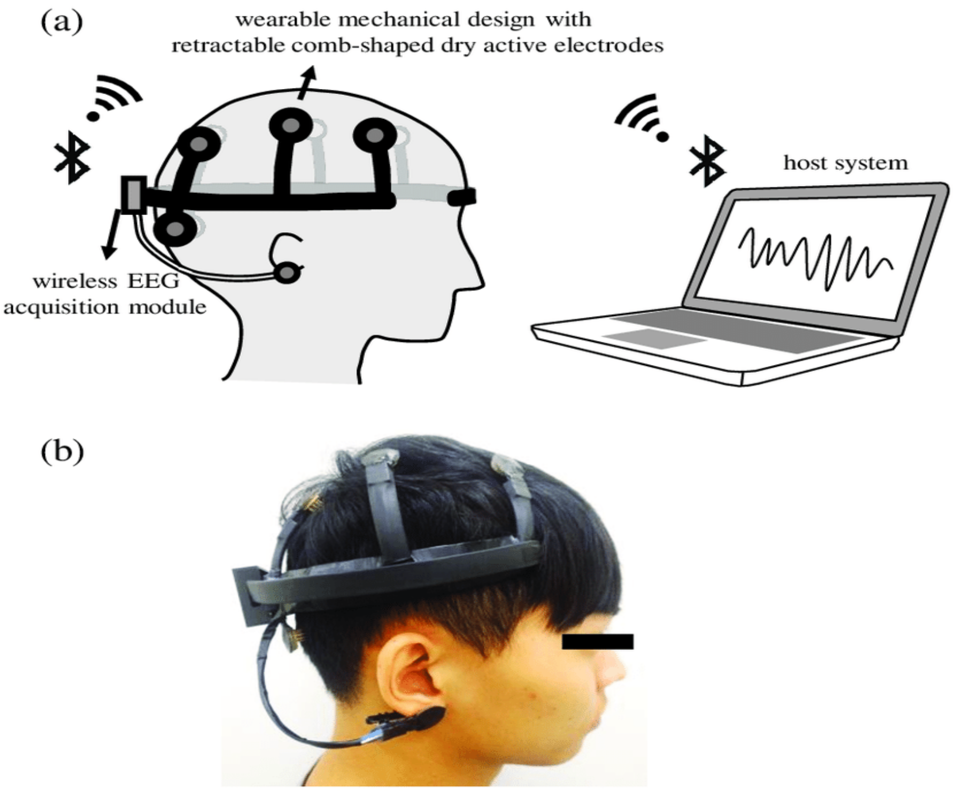


Figure 5.3.5 wearable electroencephalography (EEG) system with dry electrodes.

- Figure (a) is a schematic diagram showing the components of the system. It depicts a side view of a head wearing a device with several comb-shaped electrodes positioned on the scalp.
- These are labeled as "wearable mechanical design with retractable comb-shaped dry active electrodes". Wires connect these electrodes to a "wireless EEG acquisition module" situated near the ear. The module wirelessly transmits EEG signals, indicated by radio wave symbols and a Bluetooth symbol, to a "host system," which is shown as a laptop displaying a sample EEG waveform.
- Figure (b) is a photograph showing a person wearing the wearable EEG device. The device consists of a frame that fits around the head, with several electrode units making contact with the scalp through the hair. A cable runs from the device to a module placed near the ear, similar to what is depicted in the schematic diagram in (a).

wearable devices for brain activity monitoring are a rapidly evolving field with significant potential to impact various aspects of health, wellness, and human-computer interaction. They offer a convenient and non-invasive way to gain insights into brain function and are finding increasing applications in everyday life and specialized domains.

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