Glucometer: How can we avoid the pain of pricking our fingers?

A glucometer aims at measuring how much glucose you have in your blood to tell you whether you have diabetes or not.

Therefore, we need to prick our fingers to give a few drops of blood to the glucometer every day for a test.

How a commercial glucometer works (invasive & painful)

We will see an increased amount of current in the device when we have the electrodes exposed to your blood.

It follows this principle:

When you turn on the device, you have already applied the specific voltage, where the electrode is sensitive to the glucose. The current is proportional to the concentration of glucose to calculate the data for us.

It can follow this principle [1]:

glucose + GOD_{ox} $\rightarrow$ gluconolactone + GOD_{red}

where GOD_{ox} is the enzyme that reacts with glucose and is fabricated as the electrode probe for glucose. The more glucose you have, the more oxidation reaction there is on the electrode, the higher current it measures, and the higher possibility you have diabetes.

Non-painful glucometer? Three other options in research

There are three other types of glucometers in academic research. They are all electrochemical devices measuring glucose content in biofluids such as blood, saliva, and sweat.

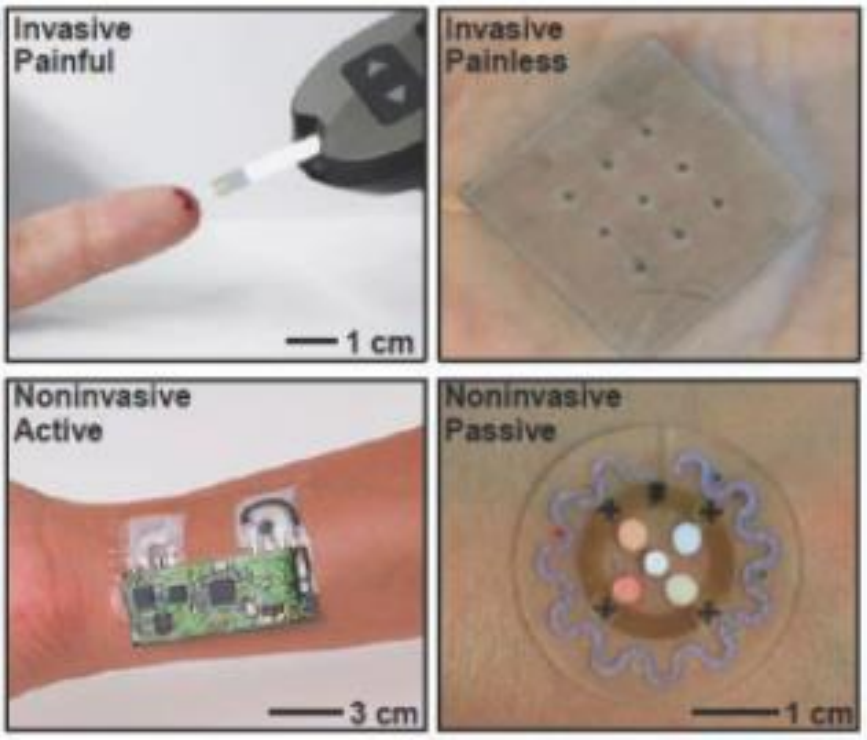


Figure 1 The four types of glucometers. Adapted from [1].

- Invasive and painful device. This is the commercial glucometer. The blood test is the most accurate up to now. In blood (inner body fluids), the concentration is highest among the biofluids.
- The invasive and painless device. We use microneedle as electrodes of the sensor that does not cause pain and monitors the blood sugar level.
- The Non-invasive and active device. The glucose in the interstitial fluid is extracted using the principle of (reverse) iontophoresis (Figure 2).
- Wearable and disposable: non-invasive and passive. It measures the glucose in saliva, tears, and sweat. In these biofluids, the concentrations of glucose are much lower than in the blood, so the device needs to have high sensitivity and selectivity. Usually, you need nanostructured electrodes to fabricate this kind of glucometer [1].

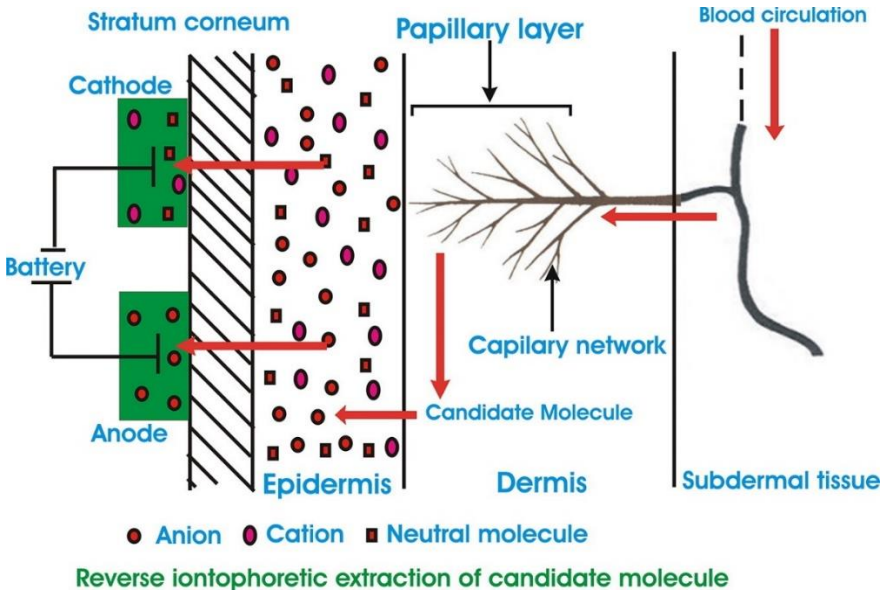
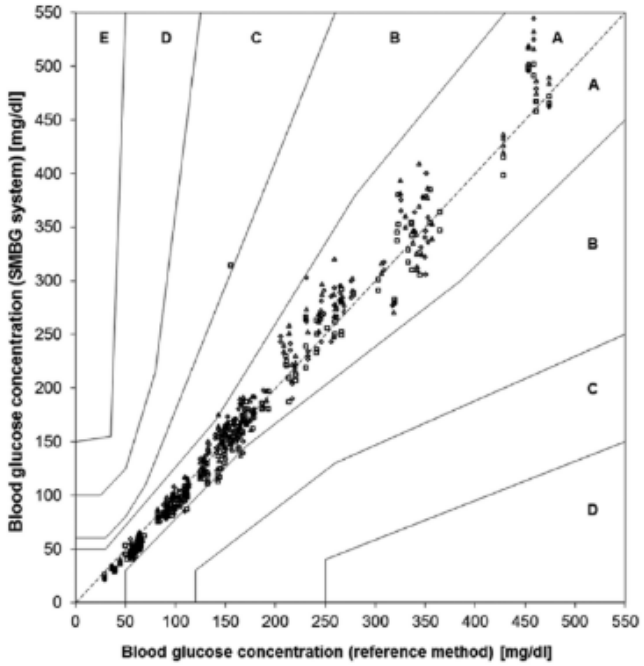


Figure 2 Reverse iontophoretic extraction of candidate molecule. Adopted from [2].

You make two points of your skin connected in a circuit with a battery (Figure 2). The positive side of the battery (anode) will attract cations from your blood in your capillary network. And the negative side of the battery (cathode) will attract the anions.

Can we have commercial non-invasive glucometers in the future?



CEG zone	Risk to patient
A	No effect on clinical action
B	Little or no effect on clinical outcome
C	Likely to affect clinical outcome
D	Could have significant medical risk
E	Could have dangerous consequences

Figure 3 Consensus error grid (CEG) and the meaning of its 5 zones. Adopted from [3].

The consensus error grid (CEG) is a diagram of measured value vs. reference value. The diagram is divided into 5 zones A-E. According to the international standard, 99% of measurement results of glucometer need to be within CEG zones A and B for premarket approval.

Noninvasive glucometer had 99% data points in CEG-zone A and B (91.1% and 7.8%). It is less accurate than invasive glucometers (100% within CEG-zone A) but still potentially suitable for frequent pain-free glucose monitoring [4].

References

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[3] G. Freckmann, C. Schmid, A. Baumstark, M. Rutschmann, C. Haug, and L. Heinemann, "Analytical performance requirements for systems for self-monitoring of blood glucose with focus on system accuracy: Relevant differences among ISO 15197:2003, ISO 15197:2013, and current FDA recommendations," *J. Diabetes Sci. Technol.*, vol. 9, no. 4, pp. 885–894, 2015.

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