Lab-on-a-chip implants : a mini laboratory under the skin

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We have realized an implantable and wearable system for the continuous monitoring of human metabolites, such as glucose, lactate, ATP, etc.. The implantable portion of the device consists of a cylinder of 2.2 mm in diameter and 15 mm in length to be inserted in the interstitial tissue. The implanted device houses five electrochemical biosensors for the simultaneous monitoring of metabolites, as well as temperature and pH sensors for calibration, and it transmits data to a wearable skin patch in close proximity. Electrochemical biosensors consist of electrochemical cells, biological recognition elements and the electronics for carrying out measurements. The biological element is typically an enzyme that is selective for a specific compound and is capable of promoting a chemical reaction with the generation of electrons in the electrochemical cell. Electrochemical biosensors offer numerous advantages to be applied on implantable devices, among which relatively simple electronics and compatibility with micro-fabricated electrodes. The biosensors are placed on a silicon interposer which is connected to a data acquisition and transmission microchip. All is encapsulated in a flexible outer casing in polydimethylsiloxane with an opening that hosts a membrane that allows the metabolites to get in touch with the biosensors. Experiments in mice have shown low levels of toxicity of this implant with the current encapsulation. A CMOS integrated circuit, with an approximate size of 3 × 1.5 mm, is used for the on-board generation of the voltage ramps required by the electrochemical measurements. Due to the limited size of the implantable device, batteries cannot be hosted in the tiny implant. Therefore, inductive coils are placed under the interposer for power harvesting, as well as for data transmission. The device works in connection with a patch located on the skin in the body area where the implant is placed. The patch produces an electromagnetic field that supports power transmission to the implant, as well as bidirectional data transmission to the implant and data re-transmission via a Bluetooth connection to portable devices, such as a smartphone, a tablet, or an external control station. Dedicated interfaces for both smartphone and remote laptop were designed to communicate with the implantable device and plot the received data. The doctor, for example, can remotely choose the metabolite to monitor and follow the behavior in real-time. Otherwise, data can be stored in the memory of the phone or of the laptop and analyzed by the expert subsequently.