Bacteria-on-a-chip: emergence of digital medicine

Digital medicine has become an inseparable part of the advanced human society. It provides a holistic sphere of care, cure and management empowered with latest developments in information technology, sensor design and genomics[1].

Bacteria-on-a-chip (BaaC) is the most recent and novel inclusion of this era. The motivation behind such intrinsic hybrid medical approach relies on the current need of real time and pervasive computation for smart healthcare[2]. In this approach, a type of synthesized bacterial strain is made useful by responding to a stimulus into a wireless signal.

The fundamental mechanism behind BaaC is the amalgamation of an on-switch DNA coupled with a given code for bacterial bioluminescence. The improved genetic circuit is then associated with the bacteria strain (e.g. *Escherichia coli*) of the target patient-body (i.e. human, rat, pig, etc.)[3]. The whole system is then encapsulated within a body-safe semipermeable membrane, i.e. capsule. Such BaaC is also powered with micro-batteries integrated with a microprocessor assembly to send the perceived signal outside of the patient-body. Usually such signals are received by smartphone-based apps via wireless Bluetooth communication.

Practically, a BaaC module is ingested by the patient. After swallowing, it goes into the gastrointestinal (GI) tract to monitor internal bleeding or infection. When the BaaC capsule comes in contact with the GI tract, the external fluid goes inside the capsule via the semipermeable membrane through diffusion. When the BaaC module encounters the targeted blood or infectious molecules, pre-engineered strain is triggered automatically. Normally, BaaC induced bacteria strains are placed inside the micro-wells which are fabricated inside the BaaC capsules. Such filled-in wells emit light when associated with the targeted blood molecule. Pre-installed photo resistors receive the emitted light from the wells. The information is then transmitted to the microcontroller for further processing.

A recently developed BaaC consumes less power, i.e. 13 mW and is equipped with 2.7 V battery which is susceptible to acidic fluid of the GI tract. The BaaC capsule is 3.81 cm in length and can stay inside the GI tract for about 45 days[5]. Upon completion of the task, BaaC module is automatically expired inside the GI tract. Otherwise, the BaaC module get excreted from the body.

The advantages of BaaC modules are that they are ingestible, automatic, robust, side effect-free, wireless communication is possible, self or semi-operative, suitable for one-time use, capable of real-time signal transmission, can circumvent surgical procedure, can be manifested remotely and cost-effective. However, the disadvantages could be possible hack, intrusion, security breach or ethical orientation. Nevertheless, BaaC seems to be the most promising technology that could reshape digital medicine in the near future.

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Research performance in India during the 2011–2015 window

Prathap[1–5] curated material from a web application[6–9] to focus on various aspects of scientific excellence in universities and research institutions in India in major subject areas using Scopus data collected for the SCImago Institutions Ranking[10]. During 2008–2012, only 70 unique institutions in India had published more than 500 papers in at least one major subject area[1]. Altogether there were 213 Units of Assessment (UoAs) reflecting the fact that many institutions had exceeded this threshold in multiple subject areas. The latest data covering scientific articles published during the window 2011–2015 cover 24 major subject areas and there are now 120 institutions and 353 UoAs, showing a steady and impressive progress over recent years.

A stiff criterion is imposed to make the cut – institutions must have published at least 500 articles, reviews and conference papers in each category within the publication period (2011–2015). The full list of institutions that have made the cut from India as well as the subject categories is available with the author. Table 1 shows the state-wise dispersion of institutions and UoAs in the latest excellence mapping exercise.

Nine insitutions with a pan-India presence appear in the table. These are the Academy of Scientific and Innovative Research, Council of Scientific and Industrial Research, Defence Research and Development Organization, Indian Council of Agricultural Research, Indian Council of Medical Research, Indian Space Research Organisation, Indian Statistical Institute, National Institute of Pharmaceutical Education and Research and the Public Health Foundation of India. The remaining are distributed state-wise. As was seen in the National Institutional Ranking Framework (NIRF), Tamil Nadu with 23 institutions and 74 UoAs accounts for nearly a fifth of India's presence in the global scenario. New Delhi accounts roughly for another