Towards ubiquitous laboratory testing: vending machine laboratory

Nyein Aung Chan[1], Tze Ping Loh[2], Chun Yee Lim[1]

[1]Engineering Cluster, Singapore Institute of Technology, Singapore, Singapore; [2]Department of Laboratory Medicine, National University Hospital, Singapore, Singapore

Correspondence to: Tze Ping Loh. 5 Lower Kent Ridge Road, Singapore 119074, Singapore. Email: tploh@hotmail.com.

Laboratory medicine is a highly technology-driven specialty. It has adopted the internet of things, cloud computing, and artificial intelligence to improve the performance of automated analytical instruments and the connectivity and capability of point-of-care devices (1).

Despite these technical advances, laboratory medicine faces several key challenges. There is a chronic shortage of manpower, caused by funding cuts, demographic shifts, and competition for talent with other fields (2). Another major concern is the inequity in access to laboratory testing (3). Of particular concern is the under-served communities such as those in rural or lower socio-economic areas, which may lack laboratory testing facility due to the high set up costs and skilled manpower. Moreover, the increasing frequency of pandemic poses higher biosafety risks to laboratory staffs.

Hitherto the clinical laboratory is mainly served by two opposing ends of the instrumentation spectrum. The relatively large, highly automated analyzers have high throughput and a relatively large on-board menu. These analyzers require relatively high efforts in daily maintenance and quality control that are performed by skill laboratory staffs. In contrast, the miniaturized point-of-care devices with relatively restricted test menu can be operated by non-laboratory trained users. These devices have relatively low maintenance requirements and limited quality control. The analytical performance of the larger analyzers is generally superior as compared to the point-of-care devices.

Vending machines are ubiquitous, selling everything from a drink to a car. The general dimensions and form factor of a vending machine enable it to fit in various environments, both indoors and outdoors, with minimal space set up. We envision a laboratory instrument in the form of a vending machine which represents the missing link in the current laboratory instrument line-up to address the unmet needs. The idealized specifications for such a vending machine laboratory are presented in this paper (*Figure 1*).

A vending machine laboratory occupies a similar footprint as a conventional vending machine, with regulated internal environments that allows placement of compact, automated instruments and sample archive and disposal. It can be placed in various healthcare facilities, including mobile clinics.

Healthcare workers inputs their credentials and patient details through scanning of predefined 2D-barcode format or manual input using a touch-screen interface. Following this, the required laboratory tests are ordered from a menu that has been optimized for the local clinical needs and generates the sample label. It is conceivable that the vending machines can be directly linked to the computerized clinician order entry to allow seamless sample labelling at the point of collection.

After labeling, the sample is introduced into the vending machine laboratory where robotic arms will scan the orders, subject the sample to centrifugation, remove the cap and introduce the sample to the analytical units. Subsequently, the tests will be performed on cartridge-based analytical units that are discarded after use, without generating liquid waste. The remaining sample will be recapped and stored in a refrigerated compartment for disposal or for retrieval for subsequent additional testing in a core/referral laboratory. An onboard ultraviolet light and air filtration system ensures the biosafety requirements are met.

The laboratory results are transmitted securely and wirelessly (or in print) to the ordering clinician. The

Vending machine Lab

The transparent windows invite the users a glimpse into the sophisticated technology that provide this critical health information and demystifies the process behind it

Robotic arms perform pre-analytical, analytical and post-analytical tasks

Modular laboratory machines to cater to local medical needs

Large touchscreen user interface for intuitive test ordering

RFID scanner for user identity verification and payment
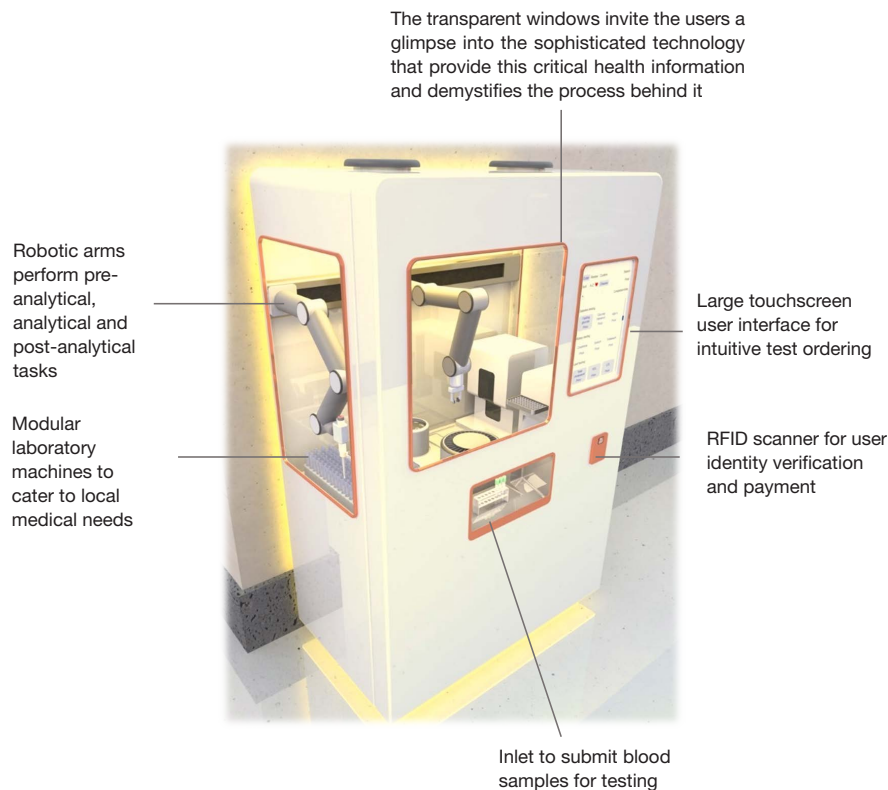
Inlet to submit blood samples for testing

Figure 1 A mockup of an idealized vending machine laboratory. RFID, radio frequency identification.

analytical performance of the analyzers is monitored by patient-based quality control algorithms using the data generated, which can be networked to increase the statistical power (4). The inventory of the consumables and the conditions of the hardware are remotely monitored through sensors and internet of things. A laboratory staff (or vendor) periodically (e.g., daily) reloads the consumables on the analyzer and retrieves the biohazard wastes for disposal or archived samples for further analysis (if test not available onboard).

A vending machine laboratory can address the aforementioned challenges. When placed in a hospital setting, it can remove the requirement for a 24/7 core laboratory yet meet urgent clinical demands. This will reduce the laboratory manpower requirement, enhance the working conditions of existing laboratory staffs and improve the appeal of laboratory profession. The significantly lower technical knowledge and set up requirements of a vending machine laboratory meant that it can be placed in locations that traditionally may not be viable for a

working laboratory, thus democratizing laboratory testing. Additionally, the sample-to-result workflow of the vending machine laboratory minimizes biohazard risks for laboratory staffs, and potentially enabling its designation as a dedicated testing facility during pandemic.

The development in the necessary technologies, including robotics, compact testing instruments, sensors, quality control algorithm, etc. are sufficiently mature and can be readily integrated. Already, an enterprising manufacturer has taken the first steps towards this goal (5).

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Footnote

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