Opinion Paper

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Emerging technology: a definition for laboratory medicine

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Abstract: The term "emerging technology" (ET) is used extensively, and there are numerous definitions offered, but to our knowledge, none specifically encompass the field of laboratory medicine. An ET definition that incorporates the overarching IFCC aim of "Advancing excellence in laboratory medicine to support healthcare worldwide" would clarify discussions. We discuss key aspects of the term "emerging technology(ies)" as it applies to laboratory medicine with a view to laying the foundations for a practical definition for the profession and propose the definition of an ET as "*An analytical method or device that by virtue of its stage of development, translation into broad routine clinical practice, or geographical adoption and implementation has the potential to add value to clinical diagnostics*".

Keywords: disruptive technologies; emerging technology(ies); innovation; laboratory medicine.

Introduction

The term "emerging technology" (ET) is used extensively, and there are numerous definitions offered including: "*a new tool with promising potential*" [1]; "*a technology the use of which will benefit many sectors of the economy and/or society*" [2]; "*those that can have a significant impact on the economy*" [3]; "*those that have the potential to gain social validity in the next 10 to 15 years*" [4]; and "*the development of emerging technologies refers to technical, institutional and social change*" [5]. Keywords used in definitions include "*innovation*", "*new*", "*relatively fast-growing*", "*future impact*", "*socio-economic domains*", and "*uncertainty*" [1, 6–8]. Whilst the term ET is used freely, there is no consensus definition and therefore variations in perceived meaning can lead to confusion and uncertainty [1, 6, 7, 9].

Previously the International Federation of Clinical Chemistry and Laboratory Medicine's Emerging Technology Division (IFCC-ETD) has used the definition developed by Rotolo and colleagues to define ET in the context of laboratory medicine [7]: "*a radically novel and relatively fast-growing technology characterized by a certain degree of coherence persisting over time and potential to exert a considerable impact on the socio-economic domain(s) which is observed in terms of the composition of actors, institutions and patterns of interactions among those, along with the associated knowledge production processes. Its most prominent impact, however, lies in the future and so in the emergence phase is still somewhat uncertain and ambiguous*" [7]. This definition is limited as it does not actually define technology itself and whilst useful it is not specific enough to help interpret what is an ET for the overarching IFCC aim of "Advancing excellence in laboratory medicine to support healthcare worldwide" [10].

To facilitate and provide clarity to the ongoing discussions, a clear definition of emerging technologies in the context of laboratory medicine is warranted. Whilst many definitions have been developed across a broad range of industries, to our knowledge, none specifically encompass the field of laboratory medicine. Here we discuss key aspects of the term "*emerging technology(ies)*" as it applies to laboratory medicine with a view to laying the foundations for the development of a practical definition for the profession and propose a candidate definition.

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Key questions

We pose the following key questions to aid in the development of an appropriate definition of an ET for laboratory medicine.

1 What is the context of "emerging"?

The term emerging in "*Emerging Technology*" can denote a nascent technology that is progressing through the development process and is beginning to be evaluated or implemented by early adopters in laboratories. In this context Technology Readiness Levels (TRL) [11, 12] chart the progress of a technology, beginning with "Basic principles observed and reported" (Level 1) through successive levels corresponding to proof of concept, validation and prototyping, ending with "System proven in operational environment" (Level 9) (Figure 1) [11, 12]. Arguably, the technology would be considered emerging beginning with Level 2 (Technology concept and/or application formulated), and continue to be emerging through to the final Level (i.e., Level 9).

The innovation adoption curve developed by Evertt Rogers is also relevant to the context of emerging and ETs [14]; Figure 2. This curve is divided into innovators, early adopters, early majority, late majority, and laggards. There is a "*chasm*" described between the early adopters and the early majority that impedes the implementation of an ET, which often is associated with the high cost and uncertainty associated with the ET that can dissipate as it is adopted (network effect). Whilst there are limitations of this behavioral change theory, including that it was not specifically developed for public health, a pragmatic review of the curve may aid in developing a data driven (prescriptive) definition of ET for laboratory medicine. In our view, the first two sections (16%) of this innovation adoption curve could easily fit into an emerging technology definition [15]. Furthermore, this curve has been applied in examples from medical science including diabetes technologies [16].

An ET can cause change and precipitate the need to manage the change. There is a well-recognized change management curve divided into the major components of Initial Enthusiasm, the Trough of Disillusion, Cautious Optimism, and Stability of Implementation. In our opinion the development of an ET would involve the first three components. Emerging in ET can also denote a technology that is already developed and used elsewhere but only now being implemented (i.e. creating change) in a new application/discipline. In a simple description, Veletsianos states that "*a technology is still emerging if it is not yet a 'must-have'*" [1].

2 Is there a country-by-country difference in ET?

The notion that an ET definition for laboratory medicine should include consideration on a country by country basis is supported by Halaweh and colleagues who looked closely

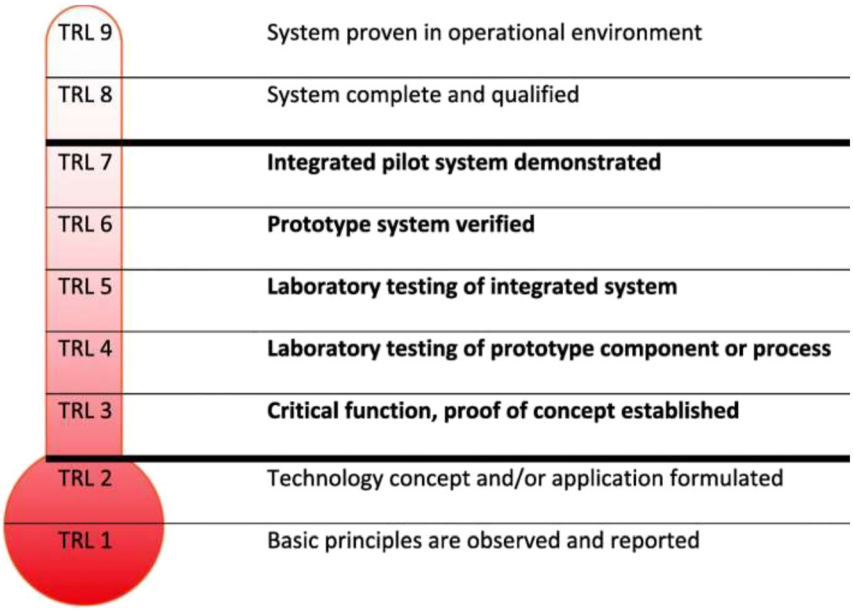

Figure 1: The determinants for an efficient translation of emerging technologies. Reproduced from [13].

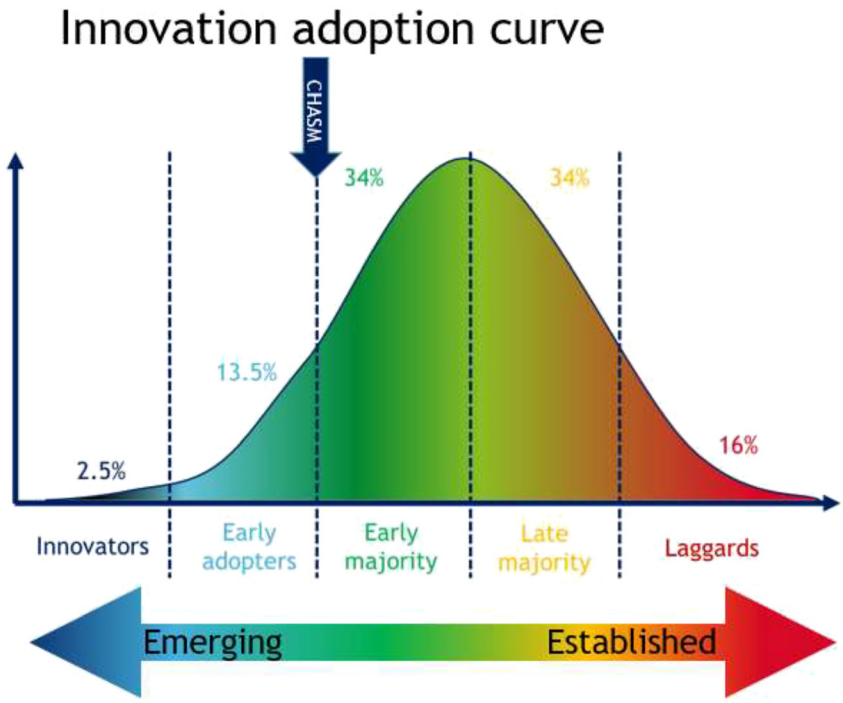

Figure 2: Relationship of the innovation adoption curves to emerging technology implementation success. Adapted from Ref. [14] https://www.valuebasedmanagement.net/methods_rogers_innovation_adoption_curve.html.

at ET definitions and state that "technology can still be considered emerging in one context even though it has been considered established in another" [6]. Further to this, ET can be dichotomized into: 1) the relatively few ET creating countries have faster adoption and therefore appear to be leaders; and 2) the many ET using countries that are behind on adoption and therefore always seem to be catching up. In this regard, broadly speaking developing countries have slower adoption than developed countries.

There are many drivers for an ET (e.g., gaps in clinical care, consumer demand), but the primary driver for an ET is socioeconomic. Generally, richer countries spend more on healthcare and hence, are better placed to develop new technologies, and other size comparisons are secondary. Therefore, ET needs to be defined per country [17]. As such, socioeconomic status is a primary influencer for uptake of ET and globally, the adoption of ET varies between countries. This is also supported by Rogers change theory which describes four elements as "*influencing diffusion of new ideas through cultures, these being: (i) innovations (a new idea, practice or object perceived as new), (ii) communication channels (mechanisms for messages to travel), (iii) time (influencing decision making and the rate of adoption) and (iv) social systems (groups)*" [14].

Often when considering an ET, it is presumed that because the technology is commonplace in one country, such as the USA, it is no longer emerging. Therefore, to counter this fallacy a definition for laboratory medicine should recognise these global differences.

3 Can we use a published metric to define ET for laboratory medicine?

Although, various published metrics may be useful for identifying technologies that might be the basis for an ET, it is probably impracticable to set quantitative criteria (e.g., number or rate of increase of patent applications or scientific papers). More specifically focused on laboratory medicine is the use of external quality assurance program data which may reveal the emergence of new analytical technologies (e.g., testosterone measurement principles over time) [18] but once again it is likely impracticable to set quantitative criteria.

Conclusions

In conclusion, we propose that an Emerging Technology in laboratory medicine is:

> *An analytical method or device that by virtue of its stage of development, translation into broad routine clinical practice, or geographical adoption and implementation has the potential to add value to clinical diagnostics.*

This definition characterizes technology as both methods and devices, and emerging in terms of stage of development

or translation into practice. It also caters for geographical differences in the emergence, and links the technology to value in clinical diagnostics. Furthermore, reference to this Laboratory Medicine specific definition will add clarity for future discussions.

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