Opinion Paper

Larry J. Kricka*

History of disruptions in laboratory medicine: what have we learned from predictions?

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Abstract: Predictions about the future of laboratory medicine have had a mixed success, and in some instances they have been overambitious and incorrectly assessed the future impact of emerging technologies. Current predictions suggest a more highly automated and connected future for diagnostic testing. The central laboratory of the future may be dominated by more robotics and more connectivity in order to take advantage of the benefits of the Internet of Things and artificial intelligence (AI)-based systems (e.g. decision support software and imaging analytics). For point-of-care testing, mobile health (mHealth) may be in the ascendancy driven by healthcare initiatives from technology companies such as Amazon, Apple, Facebook, Google, IBM, Microsoft and Uber.

Keywords: AI; future; mHealth; predictions; robotics.

Introduction

Attempts to predict the future have often been spectacularly wide of the mark, especially in the area of electronics and communications. Predictions have incorrectly foretold the lack of demand (e.g. computers) or the demise of commercial products (e.g. iPod), or pointed to the future success of products that never saw the light of day (e.g. the nuclear powered vacuum cleaner) [1].

Predicting the forces that will shape the future of laboratory medicine is complicated [2]. Laboratory medicine is multifaceted. It is comprised of different disciplines (e.g. chemistry, histopathology) it is diverse (e.g. different types and sized laboratories) and it is practiced in different locations (e.g. central laboratory, point of care). The vital role played by laboratory medicine in healthcare is also a strong driving force for change in the context of new tests with medical necessity supported by standards of care or medical guidelines (e.g. troponin) [3].

***Corresponding author: Larry J. Kricka,** Professor Emeritus, Department of Pathology and Laboratory Medicine, University of Pennsylvania Medical Center, Philadelphia, PA 19104, USA, E-mail: kricka@pennmedicine.upenn.edu

Past predictions for a decade into the future

One test of predictions is to compare the current state of affairs with predictions made approximately 4–20 years ago (Table 1A) [2, 4–10]. Some aspects of 2018 are recognizable in these predictions, but others have not been realized (e.g. mass spectrometry for protein expression profiles has not entered mainstream testing). For other broad-based predictions, some level of success has been achieved, e.g. DNA chip technology is commonplace (e.g. Affymetrix, Illumina chips), and miniaturization of analytical devices in combination with nanotechnology has found application in sequencing, e.g. nanopores (Oxford Nanopore, Two Pore Guys) and nanowells (Pac-Bio).

Over half-way to these predictions

More recent predictions made about 2020 back in 2012 have focused on the central role of the smart phone in medicine and testing and the large number of individuals who will have had their genome sequenced [7, 8]. Certainly, the scope of apps, plug-in medical devices (e.g. ultrasound) [11, 12] and analyzers (e.g. sperm tester) [13] for smartphones has increased since 2012, but it is still unclear if this type of mobile health (mHealth) will dominate in 2020. Likewise, the falling costs of sequencing have stimulated this type of testing, and as of 2017, 500,000 genomes had been sequenced. Moreover, direct-to-consumer genetic testing companies have seen considerable growth, e.g. 23andMe – 2 million genotyped customers; Ancestry DNA – 4 million members [14, 15]. Also, we are awaiting the outcome of the various large-scale genome projects (e.g. US Million Veteran Program and AstraZeneca 2 million

Table 1: Predicting the future of laboratory medicine.

A. Past predictions for a decade into the future
Prediction made about 2006–2016 in 1996 [4]
Preventative medicine focus/integration of molecular medicine, information and computer technology/predictive tests (risk factors)/ miniaturization of analytical devices and DNA chip technology/strong influence from molecular biology, genomics, robotics, microelectronics and informatics, pharmacogenomics. Profiling, nanotechnology/large scale hyperlinked data banks for patient care and new informatics tools and systems/MS for protein expression profiles
Prediction made about 2007–2017 in 1997 [5]
Molecular diagnostics, near patient testing (via biosensors), image analysis, robotics, information management (telepathology, voice recognition)
B. Over half-way to these predictions
Predictions about 2020 made in 2012 [6]
Evaluations done from your home with one of the most essential components of care for both you and your physician – the smart phone
Predictions about 2020 made in 2012 [7]
Everyone will have had their genome sequenced
Predictions about 2020 made in 2012 [8]
Smartphone the hub of medicine
Increasingly common that people will have their genome sequenced
Predictions about 2026 made in 2006 [9]
Laboratories organized as large supra-regional tertiary centers/high dependence on robotics, automation and humanoid technology/ telemedicine (remote controlled microscopy, remotely accessible telepathology workstation platforms)/integration of hematology, chemistry, etc. into blood sciences/nanorobots for monitoring human disease/hand-held devices for top eight infectious disease testing/ high-density SNP arrays commonplace/smart medical implants (biosensor + fuel cell)
C. Longer-term predictions
Predictions about 2023–2062 made in 2012 [10]
Check-ups by cell phone
Predictions about 2063–2122 made in 2012 [10]
Connected body – vital signs checked around the clock via tiny sensors

genomes project) [16], and these will hopefully present new insights into diseases and provide the basis of new diagnostic tests.

Predictions made in 2006 for a date now less than 10 years away (2026) contain a mixture of hits and likely misses (Table 1B). For example, recent moves in the UK validate the prediction for large supraregional tertiary laboratories [17], but others, such as an *in vivo* diagnostic role for nanorobots, still seem unlikely from a 2018 perspective. However, the prediction of a high dependence on robotics, automation and humanoid technology in the future does seem to be valid in view of the increasing use of robots in hospitals (e.g. delivery, greeting, helper and telepresence robots) and clinical laboratories (e.g. Yaskawa Motoman dual arm robot) [18, 19].

Longer-term predictions

Longer-term predictions (Table 1C) are more difficult to assess. They usually extrapolate existing technology or technology trends (e.g. cell phones, connectivity and sensors), but Asimov's prediction that by 2014 mankind will have become largely a race of machine tenders has a ring of truth [20]. Current progress in artificial intelligence (AI) and computer technology (e.g. quantum computing) points to an increasing role for rapid and sophisticated computing in the future. In fact, there has been a recent spate of FDA cleared AI-based test systems, including the IDx-DR for diagnosing retinopathy [21], an augmented reality microscope to diagnose cancer [22], decision support software for alerting providers of a potential stroke based on CT images of the brain [23], imaging analytics for cardiac MRI [24] and skin cancer classification [25].

Strategic technology trends and the movies

Another source of predictions is the annual Gartner list of the top 10 strategic technology trends, and this

provides valuable insights into technological developments that may impact laboratory medicine. The 2018 list includes AI, intelligent apps and analytics, intelligent things and digital twins (virtual model of a process, product or service) [26]. Based on the current healthcare advances, most of these predictions seem to provide a correct assessment of the future, e.g. AI-based clinical systems [21–25] and digital twin for hospital management and planning and *in silico* representations of an individual [27, 28].

In the movies, imagination can take us further than technology, and the Star Trek tricorder is a case in point. Current technology cannot be used to build a non-invasive device with the diagnostic capabilities of a Tricorder. The Qualcomm Tricorder XPrize results [29] provide a 2018 perspective on our progress towards this elusive goal. The first and second place winners' solutions were not a single non-invasive handheld device but, instead, multiple test devices critically enabled by AI technology.

Conclusions

What have we learned from predictions about laboratory medicine? By and large, many have correctly predicted some of the trends and changes that have taken place, but in other instances they have been over overambitious and incorrectly assessed the future impact of emerging technologies. Current predictions seem to point to a more highly automated and connected future for diagnostic testing. The central laboratory of the future, if it exists, may have fewer staff and more robots (static and stationary) that interface with connected analyzers to take advantage of the benefits of the Internet of Things and AI-based systems in the Cloud. At the point of care mHealth may be in the ascendancy founded on healthcare ambitions and initiatives from technology companies such as Amazon [30], Apple [31], Facebook [32], Google [33], IBM [34], Microsoft [35] and Uber [36].

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