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SPECIAL ARTICLE

Rapid 'technological lock in' and pathology – Is technology moving too fast?

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Abstract

The term "Lock In" as applied to Science and Technology refers to a technology which has been utilised for a certain amount of time and it has been determined that the technology is viable and cost effective. An analysis of the technological advancements in pathology over a period of time shows that the newer technologies in contrast to the older technologies are reaching a state of "Technological Lock In" much faster. Three different discoveries, the development of the autopsy as a research tool, the discovery of the microscope and immunohistochemistry illustrate how rapidly "Technological Lock In" is being achieved with the passage of time. Three probable scenarios are possible because of this rapid "Technological Lock In". Technology may continue to progress at the same pace (an ideal scenario), may plateau until pathologists accept and absorb new technologies or thirdly, develop very rapidly so that the technology may never reach pathology practice. What will the future be? How will technology influence the principles and practices of Pathology? Only time will tell.

Keywords: Technology, pathology, lock in

INTRODUCTION

An analysis of the technological advancements in pathology over a period of time shows some startling facts and figures. Advancements in the relatively older technologies like the development of the microscope, the development of histochemical stains and tissue processing accelerated for a while, changed the concepts of the practice of pathology and then reached a stage of stability. These technologies remained static and did not change very much after the stable state was reached. These technologies were important in transforming the practice of pathology. However, once they were well established technologies, they reached a steady, predictable, reliable state, a condition which is known as "lock in."

The newer technologies like microarrays, molecular biology as applied to pathology and nanotechnology - differ from the technologies that preceded them in a fundamental way. They are self-accelerating. This means that the development of these new processes results in the development of another and yet another technology; the new processes developed may be related to the original product or entirely different from it. An example is the Human Genome Project. Human DNA is now being analysed using various technologies. The analysis of human DNA leads to radical changes in therapeutics. This form of a rapidly developing technology that leads to the development of another technology which then further translates into another technological leap and continues into perpetuity is called 'autocatalysis'. These technologies with this property of perpetual self-accelerated development create conditions that are unstable, unpredictable and unreliable.[1]

What is the "Lock In" Period?

The term "Lock In period" is not derived from science and technology. It is a term derived from business administration and it refers to a period during which a loan cannot be paid-off earlier than scheduled without incurring penalties. The aim of a "Lock In period" is to ensure that there is a minimal return on the loan which has been given. This minimal return covers the lender's lending and loan administration expenses. The term "Lock

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In" may also be used to refer to a specific period of time when the lender agrees to maintain the same steady rate of interest on the loan which was agreed upon initially. This steady rate of interest will be maintained by the lender irrespective of the market rate. The term "Lock In period" is synonymous with a "Lockup period".

The concept of the "Technological Lock In" is different. If a technology has been utilised for a certain amount of time and it has been determined that the technology is viable and cost effective, it can be stated that the technology has reached a state of "Lock In".

A good example of an invention which has gone through a "Technological Lock In" is the motor car. The development of the car was viewed as the most effective means of increasing mobility.[2] Over a period of time, the motor car changed its status from being a luxury to being a necessity. As the motor car integrated into society, it underwent a change in image. Because of the increasing pollution generated by the motor car, it began to be called a "necessary evil".

As time passed, the increasing pollution generated by the motor car led to the development of several technical innovations. Some of these technical innovations were the development of catalytic converters, lead-free petrol and electronic engine monitoring systems to control pollution emissions. Consumer organisations and the media are also responsible for ensuring that the car manufacturers incorporate improved safety features in their products. Over a period of time, the technology associated with the motor car has stabilised. There is a complex network of supporting interests which has developed around the motor car. This complex web cannot be changed. This indicates that the motor car is now well into the period of a "Technological Lock In".

"Technological Lock In" in Pathology

To understand the concept of the "Technological Lock In" in pathology, it is necessary to study the progress of three different discoveries which have influenced pathology considerably over a period of time. The three innovations that we could consider are the development of the autopsy, the invention of the microscope and the development of immunohistochemistry. The selection of these three innovations is not random. These have been chosen because they have impacted the study of pathology hugely over different time periods.

The Development of the Autopsy

The Roman writers Celsus and Tertullian stated that the Alexandrians not only dissected bodies of the dead, but also performed vivisection on living criminals (as part of the punishment). However, over the centuries human dissections ceased to be performed, being unlawful in Rome and medical practice entered the doldrums for a hundred years. In the second century AD, Galen was the next person to revive the autopsy. He was the first person to describe a cancer as a "Crab Like Growth" in his book "Abnormal Tumours".[3]

Towards the end of the fifteenth century, Antonio Benivieni recorded case histories and performed autopsies on some of his patients. He published a book called "De Abditis Nonnullis ac Mirandis Morborum et Sanationum Causis" (About the Hidden Causes of Disease). In the sixteenth century, several brilliant and renowned anatomists like Vesalius (1514–1564) performed autopsies and helped to elucidate the etiopathogenesis of disease.[3]

In the seventeenth century, doctors like the surgeon Marco Aurelio Severino and Nicolaas Tulp studied diseases at autopsy, and some collected and published their findings. Examples of such publications are to be found in Boneti's "Sepulchretum sive Anatomica Practica", published in 1679.[4] Two other important compilations of that period were the "Spicilegium Anatomicum" by Theodore Kerkring and the "Anatomica Practica" of Steven Blankaart.

In the eighteenth century, there was a considerable increase in the number of autopsies which played an important role in the development of pathology. Giovanni Batista Morgagni (1682–1771) published a book called "Adversaria Anatomica".[5] Morgagni correlated the symptoms of his patients with the pathological findings at autopsy, fostering the growing belief that diseases had an anatomical substrate.

We can see that the autopsy has developed over several centuries. Starting from the second century AD to the present day, the autopsy has evolved and reached its present form. Molecular diagnostics now form a part of the modern autopsy and in its present avatar, the autopsy continues to remain relevant today. Over the last two thousand years, several books have been written on the autopsy and its relevance in clinical medicine. A PubMed search showed about 54,000 articles devoted to the autopsy using the search terms 'Autopsy pathology'. The first publication was recorded in 1883 and the last

publication was in October 2018. An analysis of the number of publications over the last 25 years showed that the number of publications remained almost constant. Between 1993 to 1998, the number of publications was 6241 and between 2013 to 2018 the number of publications was 5800. This suggests that the autopsy continues to remain relevant today. It can be concluded that the period of the "Technological Lock In" for the clinical autopsy is complete.

The Invention of the Microscope

Antony Van Leeuwenhoek in the late 17th century became the first man to make and use a real microscope. The compound microscope system was invented in the 17th century. This type of microscope incorporates more than one lens so that the image magnified by one lens can be further magnified by another. The first person to use the microscope practically was Robert Hooke who in the mid 17th century saw the structure of cells while studying a sample of cork. Hooke is also credited with being the first to use the basic three-lens configuration that is still used in microscopes today.

Thomas Hodgkin was the next great proponent of the microscope. He recorded the microscopic features of Hodgkin disease. He had also published a paper with Lister in 1832 using the microscope. With a statement which was perhaps the greatest understatement of the century, he mentioned that "Lister's compound microscope might lead to useful discoveries in the future". With increased availability, improved optics and reduced cost the use of the microscope grew exponentially.

The role of the microscope in pathology became more pronounced when Von Rokitansky and Virchow began to deduce the basis of disease. The latter came to use the microscope routinely in his autopsy studies, whereas Von Rokitansky did so less frequently, leading to erroneous interpretations of the cause of disease.[6] Another German, Johannes Müller was one of the first to use the microscope in tissue analysis. As early as 1830, he had made extensive studies of different tissues, resulting in a book "Ueber den feinern Bau und die Formen der krankhaften Geschwülste" (On the Finer Structure and Form of Morbid Tumors), which appeared in 1838.

Few advances have been made in the development of the conventional microscope over the last few decades except for the development of better optics. The number of books and papers which have been published based on microscopy are endless. The microscope has evolved over the last four to five centuries and has proved its worth. As a diagnostic tool, the microscope has completed its "Technological Lock In" period and has proved its importance as a technological tool.

The Development of Immunohistochemistry

The principle of immunohistochemistry (IHC) has existed since the 1930s, but it was not until 1941 that the first IHC study was reported. Coons and his coworkers used Fluorescein isothiocyanate (FITC)-labelled antibodies to localise Pneumococcal antigens in infected tissues.[7] Since then, with improvement and development of protein conjugation, enzyme labels have been introduced, such as peroxidase and alkaline phosphatase.[8]

Over the period of the last seventy-five years, there has been a huge amount of literature published in relation to immunohistochemistry. These studies have completely changed the concepts of histopathological diagnosis. In addition, several immunohistochemical tests are used to guide the treatment of diseases. In short, it can be stated that immunohistochemistry is now firmly in place in the practice of pathology and the web of supporting interests cannot be dislodged. In short, immunohistochemistry is now in a state of "Technological Lock In".

What Do These Examples Indicate?

The three technologies illustrated above were taken to demonstrate the fact that it is now taking just a fraction of the time it took in the past to reach a state of "technological lock in" (Fig. 1). The technological advances in different eras have been considerably different. In the present era, the time taken to achieve a state of technological lock in has been shortened considerably; the consequences of this rapid technological advancement will be described in the next paragraphs.

The Consequences of a Rapid "Technological Lock In"

Joseph Schumpeter was an Austrian-born American economist. He was the first person to lay stress on the importance of technological discontinuities in economic history. According to Schumpeter, "evolution is lopsided, discontinuous, disharmonious by nature... studded with violent outbursts and catastrophes... more like a series of explosions than a gentle,

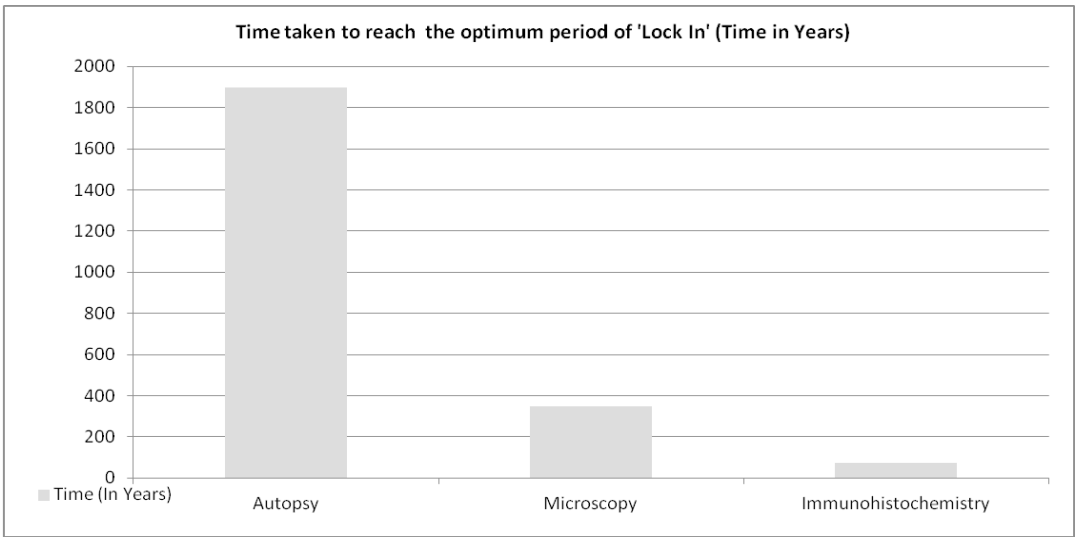

FIG. 1: A bar chart showing the relative time taken by different technologies to reach their state of 'Technological Lock In'. As the graph shows, the time taken for the development of immunohistochemistry is several times less than the time taken by the autopsy to reach a 'Lock In' state.

though incessant, transformation".[9] Schumpeter did not disagree that there are long periods of gradual development that are marked by the incremental development of dominant technologies. However, he stressed that such period is punctuated by short bursts in which new technological products, processes and associated knowledges replace the existing regimes.[10] It is these bursts of 'creative destruction' that truly drive the system in a new direction. Such a shift "so displaces its equilibrium point that the new one cannot be reached from the old one by infinitesimal steps".[11]

In sharp contrast to the Schumpeter doctrine, Marshall stated that *Natura non facit saltum* (Nature does not leap) in the preface of his classical work, "Principles of Economics".[12] Marshall felt that Nature moves in predictable directions and development occurs in small steps and not in large leaps.

Giovanni Dosi, a Professor of Economics in Italy has given a similar theory of technological development. His theory reassembles the statement of Marshall. He states that "technological possibilities and solutions that lie outside the dominant technological paradigm are rarely explored" He further stated that "there is a tendency for technological change to proceed 'incrementally' along more or less fixed trajectories. These trajectories are structured according to the pervading logic of the technological community.[13] He stated quite categorically the technology moves along fixed trajectories rather than "radically" in discontinuous leaps.

If one goes by Schumpeter's hypothesis, this rapid technological advancement is acceptable, perhaps even what should be expected. The rapid 'lock in' of immunohistochemistry in sharp contrast to the large amount of time it took for the clinical autopsy and microscopy to reach the stage of 'technological lock in' has shifted the equilibrium point of pathology to a new level. Perhaps the new level of equilibrium achieved will stabilise until the next period of rapid technological advancement.

However, if the converse theories of Marshall and Dosi are accepted, this rapid 'technological lock in' would have adverse consequences. There are three possible scenarios which could follow this rapid advancement.

The first scenario is the happy scenario and, in this scenario, technology will continue to progress at the same rate. Advancements in diagnostics will help in reducing the number of diagnostic dilemmas to a minimum.

The second scenario is more likely. It is likely that technological advancements will plateau or alternatively grow at a very slow pace. This would mean that newer technologies would take a longer time to reach a stage of an acceptable 'technological lock in'. This state would be more acceptable since pathologists would have time to accept and absorb new technologies.

The third scenario is the most disturbing scenario. Technology will develop in bursts;

however, the interval between the bursts will get shorter and shorter and revolutionary new technologies will develop at an increasingly rapid pace. It will be impossible for pathologists to absorb these technologies in their practice. As a result, these technologies will never reach their optimum state of 'Technological Lock In' and the newer technologies would not form a part of the diagnostic work up.

What will the future be? How will technology influence the principles and practices of Pathology? Only time will tell.

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