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SYSTEMS-LEVEL QUALITY IMPROVEMENT

The Times they Are a-Changin' – Healthcare 4.0 Is Coming!

Chiehfeng Chen [1,2,3] · El-Wui Loh [1,4,5] · Ken N. Kuo [1,6] · Ka-Wai Tam [1,4,7,8]

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Abstract
The Industrial Revolution brought new economics and new epidemic patterns to the people, which formed the healthcare 1.0 that focused on public health solutions. The emergence of large production concept and technology brought healthcare to 2.0. Bigger hospitals and better medical education were established, and doctors were trained for specialty for better treatment quality. The size of computer shrunk. This allowed fast development of computer-based devices and information technology, leading the healthcare to 3.0. The initiation of smart medicine nowadays announces the arrival of healthcare 4.0 with new brain and new hands. It is an era of big revision of previous technologies, one of which is artificial intelligence which will lead humans to a new world that emphasizes more on advanced and continuous learnings.

We, the humans, have been innovating and improving tools and techniques to resolve our life problems since we know how to do so, and started changing our environment systematically probably since the iron age. This process continued steadily until the Industrial Revolution occurring from about 1760 to first half nineteenth century when steam power was integrated into mechanical devices [1]. That was the time when people could travel farther by steam-driven vehicles in a shorter time. The arrival of the new production techniques created new job opportunities. The new arrivals gathered and expanded, and resulted in unplanned urbanization, causing severe hygienic and sanitation problems. Cholera spread.

Healthcare 1.0

With the evidence that the endemic disease was caused by contaminated drinking water sources, the British Government

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✉ Ka-Wai Tam
kelvintam@h.tmu.edu.tw

[1] Cochrane Taiwan, Taipei Medical University, Taipei, Taiwan

[2] Department of Public Health, School of Medicine, College of Medicine, Taipei Medical University, Taipei, Taiwan

[3] Division of Plastic Surgery, Department of Surgery, Wan Fang Hospital, Taipei Medical University, Taipei, Taiwan

[4] Center for Evidence-Based Health Care, Shuang Ho Hospital, Taipei Medical University, 291 Zhongzheng Road, Zhonghe District, New Taipei City 23561, Taiwan

[5] Graduate Institute of Clinical Medicine, College of Medicine, Taipei Medical University, Taipei, Taiwan

[6] Department of Orthopaedic Surgery, National Taiwan University Hospital, Taipei, Taiwan

[7] Division of General Surgery, Department of Surgery, School of Medicine, College of Medicine, Taipei Medical University, New Taipei City, Taiwan

[8] Division of General Surgery, Department of Surgery, Shuang Ho Hospital, Taipei Medical University, New Taipei City, Taiwan

started piping water to individual homes in 1830s [2]. This evidence-based measure had effectively prevented the occurrence and expansion of infectious diseases. Not long after that and just within a few decades, the scientific basis of germ theory and vaccine immunology was established [3]. Vaccines become generally available and the epidemics of nasty and dangerous infectious agents were prevented and controlled [4]. The combined measures of sanitation, germ controls, vaccination and epidemiology surveys had created a better environment for a healthy life in the nineteenth century. Those were the days of healthcare 1.0 in which major health problems were resolved with smart public health approaches.

Healthcare 2.0

The industrial machines kept running and changing. With the use of assembly lines, the concept of mass production was introduced into the car industry in the early twentieth century to produce cheaper products in large quantity [5]. Big was the style of the time. The same environment grew in healthcare. The supergiant pharmaceutical companies like Hoffmann-La Roche was formed a few years before the end of nineteenth century [6]. With the use of industrial mass production technology, several antibiotics were introduced to the market just a few years later [7]. It was at that time that both basic science education and clinical training become equally important in medical education [8]. Hospitals grew bigger, serviced by more professionals, and physicians were trained for specialties to deal with more patients and complicated conditions (e.g., Mayo Clinic became an internationally medical center within 1890 to 1910) [9]. Mass structure was feature of the healthcare 2.0.

Healthcare 3.0

The progression went on and speeded-up. There came the microcontrollers in 1980s that allowed manufacturing of smaller computers and facilities capable of speedy computations and large data storage [10, 11]. With the fast advancing computer technology, the tomography leaped from single images to reconstructed images, and doctors can examine the lesions with additional information and identify the diseases earlier. Also, the internet changes the way we learn. Most medical literatures can be downloaded from the e-libraries. This accelerated the development of evidence-based medicine in which in the old time the investigators had to walk-in the library and xerox-copy the papers or order them from other libraries [12]. It is obvious that the information technology had firmed the basis of healthcare 3.0.

The new brain and new hands in healthcare 4.0

Today, with automation and data exchange techniques, the Industrial Revolution has transformed to its 4.0 version [13]. Several hot topics like cyber-physical systems, internet of things, and cloud computing always appear in newspaper and conference discussions. With these 4.0 industrial inventions and new concepts, the healthcare has also transformed to 4.0 version - the era of smart medicine (Fig. 1), featured by its new brain and new hands. The new brain consists of several essential components. The precision medicine guides the treatment by using more comprehensive molecular diagnoses, e.g., genotype, protein expression, and RNA expression [14]. The artificial intelligence and big data refine the diagnostic (e.g., enhance lesion boundary and suggest diagnosis) and treatment procedures; the patients cooperate with doctors by shared decision making [15]. Telemedicine will make seeing or being seen easier, and of course, all these will not happen without the internet of things [16]. The new hands include robot, mini-laboratory, wearable devices, customized materials and three dimensioned printing which are no longer devices and scenes in fiction movies (Fig. 2). Moreover, every device operates faster and become smaller; diseases can be diagnosed from a drop of blood within minutes; plates, screws and joint implants for bone and joint surgery can be made customized, and bone scaffold can be prepared by three-dimensional printing [17]. While most of these concepts and technologies are mature and ready for dissemination, we still require time for artificial intelligence to become practically useful because it needs to learn and, learn correctly [18]. There are still rooms for all people to negotiate and judge what are to be learnt and what are not. And, unless artificial intelligence can be condensed into smaller devices, say, a robot that moves around or a simple home computer without hiding in the cloud somewhere behind the investors, we can expect one or two decades but not one or two hundred years before its take the major assisting role in medicine.

Will artificial intelligence substitutes human jobs?

The pressing movements of artificial intelligence have caused the worries of losing jobs. Will artificial intelligence substitutes human jobs? The answer is yes and no. Our world is now removing the use of human casher counters. Soon, the machines with artificial intelligence will key-in our spoken words and deliver our goods. The electrocardiogram with automatic diagnosis function and the robotic-assisted surgery like da Vinci® Surgical System have come into practice for long. Still, the cardiologists and surgeons have not lost their jobs because of artificial intelligence, and indeed, we need more.

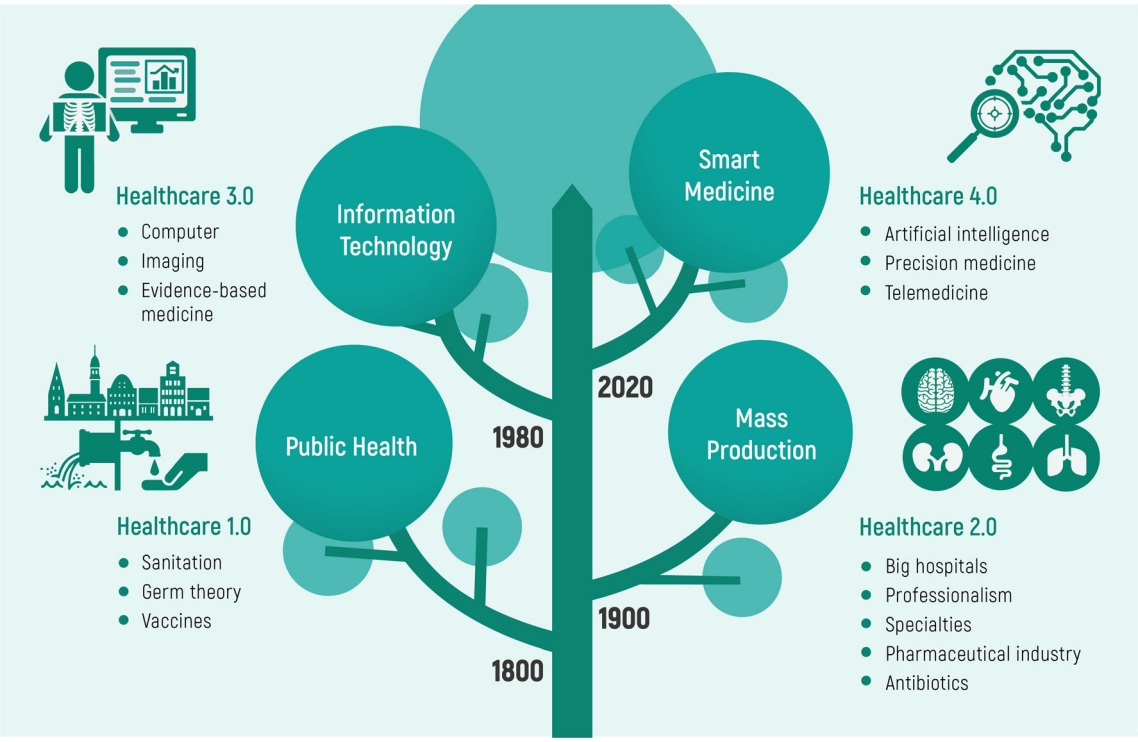

Fig. 1 The growing trend of healthcare

Artificial intelligence is to help us so that we do not need to spend time on too many targets and thus elevate our job performance.

Little doubt is there that revolution of hardware and software will surpass human labor. The structure of our society will cope with the changes, probably heading to a new world that emphasizes more on advanced and continuous learnings, so shall the medical professionals [19, 20].

Do not be afraid of the revolution. Smart medicine is better! The Times They Are a-Changin'– Healthcare 4.0 is Coming!

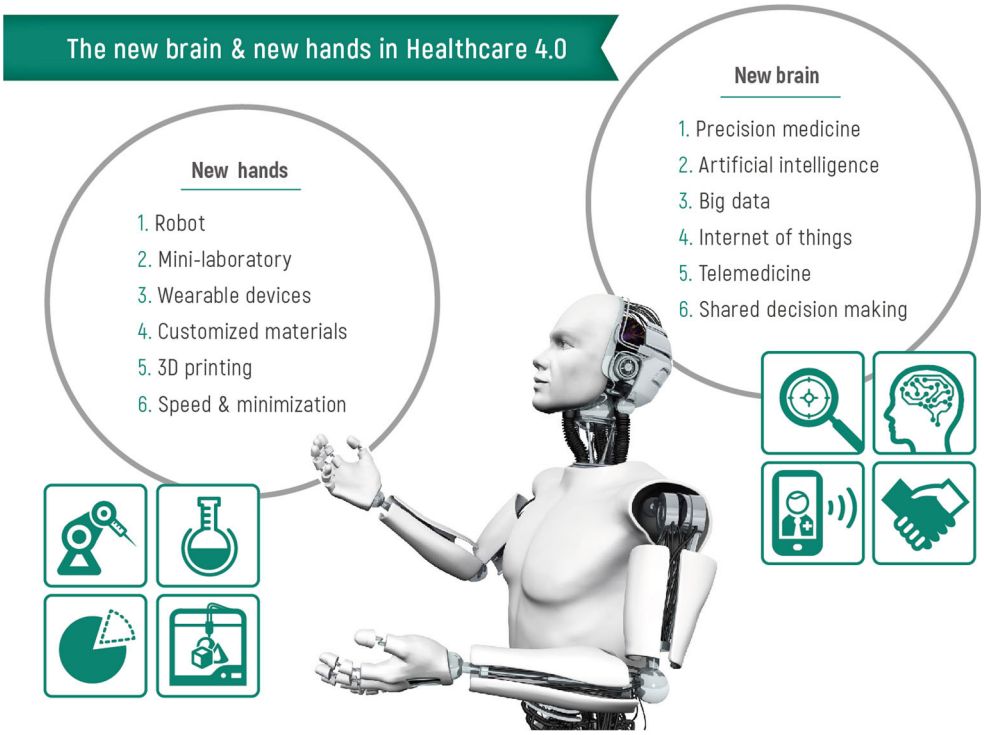

Fig. 2 The new brain and new hands in Healthcare 4.0

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