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NARRATIVE REVIEW

A REVIEW OF INNOVATION IN MEDICINE

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Received: 01 November 2021
Accepted: 15 November 2021
Published: 15 January 2022

ABSTRACT

Medicine is inextricably linked to the notions of progress and innovation which have enabled medical practitioners to diagnose and treat successfully an ever-increasing number of pathologies. The history of innovation in medicine is marked by the development of novel drugs, of anaesthesia, of antisepsis, and of the application of new surgical methods. From the 19th century onwards, which marks the development of modern medical practices, the numerous wars in the West, contributed to the exponential emergence of new medical techniques. Today, not only new methods of therapy and diagnosis are available, but new multidisciplinary medical fields provide new insights and potential for integrative methods of prevention and therapy.

Keywords: medicine, innovation, medical technology, progress

INTRODUCTION

It is difficult to trace the emergence of medical practises in human history since even in the earliest of human societies, people must have realised the importance of the development of healing practises. The earliest evidence for human disease comes from palaeopathological investigations [1][2][3] and it can be assumed that, accordingly, primitive medical practises must have arisen from the need to treat them. It is evident that early medical practises were related to supernatural beliefs, more or less [2]. Gradually, and with the emergence of organised societies, therapeutic methods became more secular and related to natural resources, as examples from Ancient Egypt (e.g. [4][5][6]) and Greece demonstrate (eg. [7][8][9][10]). Apart from Europe, medicine also evolved in South America, where innovations such as obsidian scalpels have been discovered [11], enabling surgeries such as trephinations and craniotomies [12][13]. Meanwhile, a different form of medicine, innovative in its own way, but somewhat removed from the notions of western medicine, was developed in China [14][15] and Japan [16][17], and later transmitted to Europe [18].

As it can be seen, by the aforementioned, medicine is ever evolving, both as a science and as a healing art. Through the centuries, and via the interaction between different medical beliefs and the accumulated efforts of individuals and research groups alike, medicine has moved forward, in a succession of innovation and application. It is the purpose of this article to illustrate how landmark innovations have transformed irrevocably for the best, the face of medicine, endowing it with a diagnostic and therapeutic potential, which allows for the identification and treatment of an ever-increasing number of pathologies. The focus of this article will be on western medicine, which is more reliant on technology-related innovation, and as such I will not delve into details pertaining on the advances in traditional medicine systems.

MATERIAL AND METHODS

In order to maintain a concise approach, taking into account the centuries-long history of medical innovation, I will present only such innovations made after the 19th century, which is widely held to signify the emergence of modern medicine and associated medical practises [19], with the gradual appearance of modern concepts on the causes of diseases and on the courses of treatment, such as the theories of Schwann (e.g. [20][21][22]), Koch (e.g. [23][24]) and Pasteur (e.g. [25][26]), to name but a few.

I will divide the innovations in two categories, based on their nature: innovations in therapy and innovations in medical technology. Regarding innovations in therapy, I will include in this category all such advances which contributed to the improvement of treatment (e.g. antisepsis, new surgical methods). Innovations in medical technology will deal with the advances in technology which had a direct impact on medicine (e.g. development X-Rays, development of Anger camera). It is of course impossible, even to delineate, let alone analyse, the entirety of medical innovations, which occurred in the two centuries of interest, but my aim is to present the most representative landmarks, enabling the reader to follow seamlessly the path which shaped modern medicine.

RESULTS AND DISCUSSIONS

Innovations in therapy

Regarding therapy, the development of new pharmaceutical drugs must be considered as one of the catalysts of revolutionising medical care. Prior to the 19th century, there were medicinal substances, based on plant extracts, which cannot, however, be considered drugs, in the modern sense [27]. It can be argued that the development of modern chemistry, pioneered by Lavoisier [28] enabled the introduction of chemical methods in drug discovery. Following advances by numerous scientists, and the application of the principles proposed by Gay-Lussac and von Liebig [29], chemical methods were used in biological research by Bernard, Virchow and Pasteur [27]. Pharmacology became gradually a distinct discipline, owing to the work of Magendie and others [27]. Morphine was isolated in 1817 [30], and this is considered a landmark in the development of painkillers. It spurred further research in the field of opioids, which also lead to the identification of the endogenous opioids of the human body [31]. Meanwhile, Eichengrün, in the towards the end of the 19th century, synthesised acetylsalicylic acid, commonly known today as aspirin, and introduced it in medical practise [32]. Other advances of the century included the appearance of drugs for treating cardiovascular pathologies, like digitalis [33] and nitroglycerin [34][35].

The other major landmark research pertains to the development of antimicrobial agents. Up until the 20th century, the main measure used to prevent microbial infections was sanitation and disinfection of wounds [27]. In the 1910s, Salvarsan, also known as compound 606, was produced in Germany [36] and marked the beginning of the end for syphilis, which, up until then had been debilitating and uncurable. The first sulphonamide drug, Prontosil, appeared in 1932 [36], and was the first-ever medicine which could treat a wide range of infections inside the human body. Meanwhile, in 1928, Fleming had discovered penicillin, isolated from mould [27] which was developed into a functional antibiotic by Florey and Chain [37]. From the second half of the 20th century onwards, a host of discoveries of new drugs followed, along with improvements in the manufacturing of already existing compounds. Gradually, disease-specific drugs began to enter standard medical practise, revolutionising and reforming medical practise and exponentially increasing the courses of treatment available.

As mentioned before, after the 19th century, there were marked innovations in surgical methods. Amidst all the fields of medicine, surgery is more dependent on innovations, oftentimes from sole pioneering surgeons. In addition, the true flourishing of surgery occurred once efficient methods of avoiding pain and infection had been developed [2]. Early anaesthesia was performed both locally and generally [38]. As happened in many fields, so too in medicine, war was a major impetus in the development of anaesthesiology and surgery. During the American Civil War, the sheer number of casualties necessitated a great deal of medical attention [39]. By the end of the War there was a marked advance in the use of anaesthesic agents and in the understanding of their benefits and side effects [40]. Gradually, and following the Franco-Prussian War, chloroform was also employed, along with the introduction of inhalers, to facilitate the administration of anaesthesia (e.g. [41][42]). Gradually, owing in part to the First World War too, surgical anaesthesia continued to develop, eventually crossing over to the field of civilian medicine, shaping the modern aspect of anaesthesiology. Semmelweis and subsequently Lister, introduced antiseptic methods [43], thus greatly reducing the death of patients after surgeries, which was a result not of post-operative complication but of infections. Apart from the anaesthesia, the development of drugs to combat pain, greatly benefitted post-operative recovery, along with antibiotics which minimised the effect of potential infections. Finally, the development of X-rays and other imaging techniques, which will be presented in the next chapter, enabled both pre-operative and post-operative visualisation of the pathology, facilitating a more accurate and localised surgical intervention.

Innovations in medical technology

Perhaps one of the most well-known innovations is the development of X-rays, by Röntgen in 1895 [44], which sparked the development of medical radiology and in 1896 the first radiological imaging device was used [45]. Soon enough, the dangers inherent in the use of ionising radiation [46] were realised, and this was compounded by the initial technical difficulties associated with the use of the equipment. Gradually, however, and through constant adjustment, improvement and innovation, X-ray imaging became both simple and safe [47]. Based on these early applications, other methods, like real-time fluoroscopy [48] and contrast radiography [49] were also developed, and X-rays were employed in therapeutic applications [50][51].

In the field of imaging, other notable innovations include the use of γ-rays for imaging and therapeutic purposes, along with the development of the MRI, based on nuclear magnetic resonance. Gamma rays are photons originating from the radioactive decay of nuclei [52] and are employed in scintigraphy imaging, where emitted γ-radiation is captured by Anger cameras to create two-dimensional images of the human body [53][54]. Scintigraphy, as well as the PET scan are classified as nuclear medicine methods, and employ radiotracers, which due to the nuclear decay of their components, emit γ-radiation, which when detected enables imaging. PET scans were first employed in the 1960s [55][56] and are a direct result of the application of advances in the field of nuclear physics for medical purposes. Also benefiting from advances in physics, MRI was developed in the 1970s [57][58], and subsequently improved upon, providing unique imaging capabilities, while having the added benefit of not using ionising radiation [59]. Finally, ultrasonography, better known as medical ultrasound, was developed in the early 1940s [60], and applied a few years later, taking advantage of the discovery of the phenomenon of piezoelectricity [61].

A focal point of innovation in medicine was the development of methods associated with and based on DNA. Desoxyribonucleic acid was initially isolated by Miescher in 1869, and called nuclein [62]. Further research expounded on the structure of nuclei acid and its constituting nucleotides [63] and the theories of Koltsov [64] and Griffith [65] proposed the association between heredity and DNA. In the 1930s, using X-ray crystallography methods, the first images of the structure of DNA were obtained [66]. Further experiments corroborated the early hypothesis of the DNA being the carrier of heredity [67][68]. Finally, in 1953, Watson and Crick, studying the data of previous researchers, concluded that the model of the DNA was that of the double strand [69]. A few years later, Crick described the central dogma of cell biology, and thus molecular biology was born [70].

The elucidation of the structure of DNA, and its identification as the carrier of heredity enabled, gradually, the development of recombinant DNA methods, which were subsequently employed in medicine [71][72]. Further advances in biomedical technology, enabled the development of polymerase chain reaction (PCR), which has both clinical (e.g. [73][74]) and forensic (e.g. [75][76]) applications, and of other methods, such as gene therapy [77][78] and the industrial production of proteins (e.g [79][80][81]).

Finally, one of the major advances of medical technology has been the development of vaccines. The earliest immunisation efforts, in human populations, can be traced to the process of variolation, between the 12th and the 15th centuries [82], but the emergence of vaccinology will happen much later, in 1796, owing to the efforts of Jenner [83]. While initially there were very few efficient vaccines developed, gradually, along with the aforementioned advances, and the identification of various pathogens, many vaccines against numerous diseases came into clinical practise, by the 1930s [84][85]. Following the Second World War, and the establishment of international organisations, most notably the World Health Organisation, vaccine development entered its so-called ‘‘golden era’’ [86]. By the 1980s, multivalent vaccines for various bacterial serotypes were also being developed [87][88]. Today, vaccination is regarded as one of the greatest triumphs of medicine [89], and its beneficial effects have been demonstrated time and again (e.g. [90][91][92]). However, even in such an effective medical practise, there are still adverse effects, in some cases (e.g. [93][94][95][96]), and the eradication of such cases, so as to ensure an absolute standard of safety, remains a future challenge for medical technology.

Conclusions

From the aforementioned, it can be seen that innovation has played a major role in medicine, especially since its transcendence from an empirical to a scientific field. Virtually every field of natural science has contributed and continues to contribute, enabling constant innovation and its application, concomitantly with the improvement of already-existing methods.

Owing to the constant drive of individuals and teams of researchers, through the utilisation of cutting-edge technology, occasionally with a bit of luck in their endeavours, medicine has come a long way, from its tentative scientific applications of the 17th and the 18th centuries. The existence of modern society rests in part upon the existence and the smooth function of organised health care systems. It is no exaggeration to claim that the western world would be very different, especially considering the numerous wars and pandemics of the past two centuries, had medicine remained in its pre-Enlightenment stage.

Thus far, I have presented innovations pertaining to the strictly, so to speak, biomedical part of medicine. However, innovation may be also applied, as a notion, also to concepts and approaches related to or stemming from medicine. In the 21st century, interdisciplinary research has resulted in the emergence of new disciplines, such as medical geology (e.g. [97][98]), medical geography (e.g. [99][100]) and health care marketing (e.g. [101][102]) which also studies the contribution of internet to patient information and health care seeking behaviour (e.g. [103][104][105]). Finally, a notable progress has been the development of the field of psychosomatic medicine and medical psychology, which adopts a multifaceted approach to the aetiology and the treatment of diseases [106][107][108][109].

To summarise, innovation has been a driving force behind medicine, and has depended upon combining different scientific disciplines, while benefiting from technological advances. While looking in the past, and at the exponential progress, achieved in a relatively short amount of time, it is reasonable to assume that medical progress will continue to provide novel and efficient solutions to pre-existing and arising problems, both in treatment and in diagnosis. However, as the ever expanding frontiers of medicines open new horizons, researchers and medical professionals must be cautious, not to digress from their therapeutic prerogative, and remain within the bounds of bioethics.

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