

Review Article

Galen and the Origins of Experimental Neurosurgery

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Introduction

Galen remains one of the major figures in the history of medicine which he dominated for 15 centuries. His vast output of writings, more of which survives than any other ancient writer, are very wide ranging in scope, covering all aspects of theoretical and clinical medicine as well as significant areas of philosophy. Galen was the first to attempt to formulate a classification of diseases and symptoms with a strong basis in anatomy. Like Hippocrates, whom he greatly admired, the more theoretical aspects of his medical and philosophical writings remain relevant today [1].

Galen was unequalled as a clinician for his time, displaying great acumen and reporting his successes with much self-satisfaction. There is extensive evidence of both the great respect in which Galen was held in his lifetime and the large geographical spread of his writings within a generation of his death [2]. The full scope of his work was originally published between 1821 and 1833 (20 volumes) edited by KG Kuhn which provided the Greek text and Latin translation for the majority of his surviving writings (reprinted in 1965 and 1997 by George Olms). Only a very small part of his corpus has been translated into any of the modern European languages [3].

Education and early medical practice

Galen was born in Pergamum on the Ionic coast of Asia Minor in 129 AD. The city was renowned for its shrine to Asclepius, and for its library, second only to that in Alexandria. His father, Nikon, was a well-respected, wealthy architect-engineer who took an active role in Galen's liberal early education concentrating on mathematical and philosophical subjects, notably geometry and logic. This seems to have influenced his methodical approach to medicine. His strong views on the importance of philosophy in medical training reflected his eclectic, extensive, philosophical education [1]. Indeed after his father guided him into medicine at age 17yrs, his study of philosophy continued.

Galen's life changed considerably when his father died in 149 AD and his primary medical tutor, Satyrus (a renowned anatomist) returned to Smyrna. With a considerable endowment left by his father, Galen left Pergamum and travelled for the next eight years, setting out to further his medical education. He initially went to Smyrna for a year, studying with Pelops (a noted Hippocratic commentator) and attended lectures by the Platonic philosopher, Albinus [4]. He then roamed widely in Asia Minor, the eastern Mediterranean and Egypt,

Abstract

Galen was the most influential medical writer of all time. Although a dogmatic authoritarian, he was a careful, accurate observer and original thinker. This paper details Galen's life and contribution to medicine with particular reference to, what I believe, are the origins of experimental neurosurgery.

Keywords: Anatomy; Philosophy; Experimental neurosurgery

furthering his knowledge of medications, before spending five years in Alexandria [5].

In Alexandria Galen was able to observe illness, treatments and medical philosophies as well as have direct clinical experience with patients. Also there was wide availability of pharmacological information about plants and minerals [6]. Here he studied under several famous teachers of anatomy although there is some controversy as to whether this included the famous anatomist, Numisianus, or his son, Heraclianus [1]. Also Galen seems to refute the widely held view that human anatomical dissection had ceased by the 1st.century AD [7].

“Let it be your serious concern not only to learn accurately from books the shape of each bone, but also to carry out a keen visual examination of the human bones. This is very easy at Alexandria inasmuch as the physicians there employ visual demonstration in teaching to their pupils. For this reason – even if for no other – try to visit Alexandria”. Galen, ‘On Anatomical Procedures’ 1.2 (11.220K)

Physicians from all over the Roman world gathered to study, teach and practice in Alexandria giving Galen insight into the continuing debate between conflicting schools on the theoretical basis of medicine which was to continue in his lifetime and in which he participated vigorously [4]. This was the culminating and major period of his extended medical training.

By the time Galen returned to Pergamum at the age of 28 to enter medical practice, he had impressive credentials after long and varied training equivalent to modern specialist medical post graduate studies. He was appointed as physician to the gladiatorial school, partly by demonstration of his repair of an abdominal wound in an ape [8] but also from early writings on anatomy and physiology. He remained in this position from 157 to 161 AD and thus gained very considerable experience in the surgical management of a variety of wounds and fractures as well as the opportunity to study surgical anatomy in detail [6]. Galen subsequently did not practice surgery, a view prominent in antiquity as “surgical intervention was the treatment of last resort” [9].

“The best physician was the one most capable of treating surgical conditions by means other than the knife, and particularly by diet and drugs”. Galen, ‘On Recognising the Best Physician’ (Opt. Med. Cogn.) 10, 1: CMMG Suppl. Or. 1V [10].

Despite this Galen described incisive, astute, detailed observations

on surgical practice and the use of surgical instruments. His descriptions reflected skill and pragmatism [6].

Roman period

Precisely why Galen left his successful practice in Pergamum to travel to Rome is uncertain. Hankinson suggests it was because of political unrest but Nutton feels he was motivated by personal ambition. He arrived in Rome in late 162 AD having travelled to Macedonia, Cyprus and the Dead Sea in search of mineral and herbal remedies [4].

Galen's initial stay in Rome was brief but very eventful and successful in several ways. He established his reputation by cure of his old philosophy teacher, Eudemons [2,4], as well as high rates of success in other clinical cases (he reports in his own writings). However Galen was often at odds with other medical practitioners whom, he felt, did not measure up to his exacting standards.

Galen engaged in public demonstrations and debates, often ridiculing opinions and methods he disagreed with [6]. There were several public arguments with the anatomist Martialis [11], as well as various philosophers. His public demonstrations of anatomy using vivisection in animals were theatrical spectacles [4] but were astonishing demonstrations of Galen's skill and knowledge. All this furthered his reputation but most certainly would have made him a number of enemies. However Galen had the patronage of the consul, Flavius Boethus, who encouraged and facilitated his anatomical research [5] and to whom he dedicated several books.

Galen left Rome in 166 AD and returned to Pergamum under circumstances which various sources dispute. Hankinson states (p14) that he "escaped Rome by pretending to go on a country holiday", perhaps fearing his enemies. This also coincided with an outbreak of plague in the city which he fled according to [12]. Other authors suggest he always intended to return and had business arrangements to attend [1]. However his stay was brief and in 168 AD he was summoned by Marcus Aurelius to join the imperial army on campaign in Northern Italy, arriving in Aquileia as the plague erupted [4]. Galen remained there as a treating doctor throughout the winter whilst the emperor returned to Rome, as did Galen subsequently, in the spring.

Marcus Aurelius asked Galen to join the campaign against the Germanic tribes but he declined stating that he wished to remain in Rome, having received "instructions" from Asclepius in a dream (Hankinson suggests that this confirms the view of some that he lacked physical courage but this is refuted by [13]). During the long seven year campaign Galen was responsible for the medical care of Commodus, the emperor's son. He was subsequently made Imperial Physician on the return of Marcus Aurelius after he had cured him of a "paroxysm" [4].

The seven years of the emperor's absence is said to be Galen's most productive writing period [4] with volumes on functional anatomy ("On The Utility of Parts" and "On Anatomical Procedures"), medical philosophy ("On The Doctrines of Hippocrates and Plato), and his six books of therapy ("On The Therapeutic Method). He remained in Rome probably for the rest of his life according to [14], although there is speculation that he may have returned to Pergamum [1]. His age and place of death are obscure but he is thought to have lived and continued writing until age 87 according to Johnston.

Unfortunately a significant amount of Galen's work was destroyed in a fire at Rome's Temple of Peace, a book repository, in 192 AD [15]. However there is valuable information from two short works produced late in the century ("On My Own Books" and "On The Order of My Own Books") which set out his writings in detail.

Writings

Galen dictated his vast volume of work in Attic Greek – the language of science in antiquity. His writings on basic science, anatomy, physiology, pathology and pharmacology have remained the core essence of western medical education into the modern era. Galen developed the physiological system based on the four elements (fire, air, water, and earth) and their related for qualities (hot, cold, wet, and dry), a theory which originated with Empedocles but elaborated to medical maturity by Hippocrates [16]. Galen's pathology was based around imbalance of the above four qualities and their related four humours (yellow bile, blood, phlegm and black bile), ideas dating back to Alcmaeon but first clearly formulated by Hippocrates [17]. Galen took clinical Hippocratic medicine and attempted to perfect it within a wider theoretical perspective using a framework of anatomy and physiology [18].

"There are three main factors which govern the body. It has been shown that, beside the heart as principle (organ), the brain is the foremost source of sensitivity and motility for all parts of the body, whereas the liver is the principle of the nutritive faculty. Death results from an imbalance of the humours in the heart, since all parts (of the body) deteriorate simultaneously with the heart". Galen, 'On the Affected Parts' V, 1, 2.

Apart from humoral theory, Galen also gained insight from Hippocrates into allopathic treatment principles, causal explanations for each disease, and emphasis on ethics and methodology. He followed the traditions of Hippocrates advocating diet, rest, hygienic regimens as well as bloodletting, purging and cupping [6]. Although Galen expressed unbounded admiration for Hippocrates throughout his life [16] there were areas of disagreement such as in bloodletting. The importance of phlebotomy for Galen is obvious as he devoted three major treatises to the subject but is sceptical about topological bleeding and the relevance of vein selection as advocated by Hippocrates [19].

"Some say that it makes no difference which vein one chooses to cut, since the whole body can be evacuated equally well through any of them; others, however, take the contrary view that there is a very great difference, since some veins evacuate the affected parts quickly, others in a longer time". Galen, 'Venesection against the Erasistrateans'K, X1 53.

Similarly Aristotle, to whom Galen accorded great respect and importance, is a target of criticism when he is linked with Praxagoras in regard to their misconception of the function of the heart: "they were either blind themselves or addressing a blind audience" [20]. However there is no doubt that Galen was strongly influenced by Aristotle, especially in his attention to taxonomy as well as his theory of elements and qualities [1].

Plato is the philosopher that Galen most obviously respected [20] and he built on the Platonic doctrine of the soul governed by animal, vegetable and rational spirits [18]. According to Plato the life blood

was the air modified by the three principle organs (heart, liver, brain) and distributed by the three vessels (arteries, veins, nerves) but Galen had the insight to enunciate anatomy as the key to Plato's tripartite soul with its three organs and vessels [21].

Galen believed in the universality of causation and that every event is attributable to a cause or a number of causes whether these are evident or not. This brings about the changes in the constitution that affect disease, its symptoms and affections [1]. As an example he thought a mixture of black bile and blood caused an inflammation known as scirrhus, one form of which could become cancer whereas a flux of pure black bile produced cancers [22]. Galen did not, however, distinguish between cancerous lesions, benign tumours and inflammatory growths. All of these were forms of inflammation traced to concentrations of corrupt blood [22].

Foreshadowing later ideas of bacteria, Galen refers to "pestilential seeds" of disease [23]. However he is less interested in the nature of the seeds than in why some people succumb and others do not. His conclusion is very clear: "we must always remember this principle – that none of the causes of disease can operate without a predisposition in the patient" [24]. This statement might seem only to complement Hippocratic views but in Galen's analysis, the body's inner state is of fundamental importance [23]. This remains a primary principle of medical practice.

Personality

Much has been written about Galen's inflated sense of his own importance with denigration of his colleagues [18]. He regularly vented bitter criticism in public upon those with opposing views to him [1]. He may have had a degree of narcissism and he certainly had a combative, self-serving style of writing which is, in part, exaggerated although with a firm basis in fact.

Johnston has described Galen's style of writing as pedantic, autobiographical and self-promoting with a perception of arrogance. In his writings he was capable of merciless and vitriolic abuse on those with whom he disagreed such as Asclepiades.

"Asclepiades is forced here again to talk nonsense, just as he did in regard to the urine. He also talks no less nonsense about the black bile and spleen, not understanding what was said by Hippocrates; and he attempts in stupid – might I say insane – language, to contradict what he knows nothing about". Galen, 'On the Natural Facilities' 1, 13-14

Galen regarded contemporary medicine as somewhat degenerate with disregard of the careful, methodical scientific determination necessary to secure the correct diagnosis and prognosis. He was fundamentally sincere in his belief that the truth in medicine required diligent application, and liberal education [4]. Not surprisingly Galen states that this was exemplified by himself but Hankinson believes he was capable of intellectual modesty and had the ability to change his mind. Perhaps, as Hankinson states, he saw himself as a man on a heroic mission to rescue medical science from its current poor state.

Philosophy

Galen had a detailed knowledge of earlier medical and philosophical writings, particularly Hippocrates, Aristotle and Plato [1]. Galen himself was an erudite philosopher who felt strongly that

"the best doctor is also a philosopher" referring to moral philosophy, natural philosophy and methodology [16]. Lack of philosophical training, especially in logic, physics (the science of nature) and ethics, was a criticism Galen frequently levelled against his opponents [18]. He strongly felt that philosophy, particularly ethics and logic, was an essential component of medical education and a physician's instruction.

In Galen's lifetime there was ongoing debate between the various conflicting schools of thought regarding the theoretical basis of medicine. There were two main competing theories of bodily structure. A continuum theory was based on the idea of the four primary elements or qualities involving humours which Galen supported. The atomic theory supported the view that all matter consists of minute, discrete particles espoused by Asclepiades [1]. Galen was remorseless in his opposition to atomist theories (which ultimately prevailed) and scorned the Empirics. He was very much linked with the Rationalists or Dogmatists [25].

Galen took from Aristotle teleological explanations in his writings and felt that the purpose of everything was predetermined. There was, of course, a certain popular appeal in the concept that the presumed function of an organ was because nature must have given it a purpose [6].

Galen advocated moral virtue and tried to practice it: "to follow a plan of constant moral self-improvement" [4]. He understood the uncertainties and fears of the sick, as well as the interrelations of emotion and bodily symptoms, elaborating the four fundamental humours into four personality types. These terms, phlegmatic, sanguine, choleric and melancholic, are still in use today [6]. Galen wrote on the importance of trust, bedside manner, adequate explanation and the mastery of prognosis in the doctor-patient relationship [17].

Original contributions

Galen considered his development of pulse doctrine as his greatest contribution to diagnostic medicine with over 1,000 pages of text in 16 volumes [4]. There were four treatises, each consisting of four books with robust classification and description of pulse types together with the influence of innumerable internal and external factors [18].

Although Galen made large scale use of medications, he relied on tradition and experience with his pharmacological writings coming from the latter part of his life [9]. He often relied on polypharmacy, preparing his own prescriptions, and classified medications according to the humours and qualities of hot, cold, dry and moist [6].

Galen made extraordinary advances in anatomy which were not challenged until the time of Vesalius. His dissections were of animals, primarily pigs, dogs, goats, apes and sheep [18], which he then extrapolated to human anatomy (resulting in some noteworthy errors). He described a wealth of accurate detail including the venous connection to the heart, the autonomous nature of the heartbeat and the demonstration that arteries contain blood, not air [26]. Galen was the first to describe the ureters with their function, as well as organising the bones of the skeleton with their muscle attachments [6].

Galen acknowledged his debt to the Alexandrian school, especially Herophilus [1] and Marinus, who he singles out as having resuscitated anatomy after it had fallen into neglect [8]. His public displays of anatomy in Rome were well executed and erudite, impressing medical colleagues as well as the public. Galen stated that “physicians need anatomy to the highest degree” [8] and, in a learned manner, he could easily discuss a clinical scenario to a similar situation reproducible in an animal, with anatomy as the key. Galen produced a completely systematized approach to anatomy and used anatomical knowledge as evidence of excellence in medical practice [8].

The depth and range of Galen’s anatomical works attest to the crucial importance he placed on anatomy in his medical and philosophical world. Nowhere is this shown more clearly than his neuroanatomical studies which, arguably, were the origins of the experimental neurosciences.

Neuroanatomical insight

As well as meticulous dissection, it was Galen’s mindset as a medical scientist that gave him access to structural and functional neurophysiology which he was then able to describe in exquisite detail [18]. Galen’s experimentation on animals divulged the nerve supply of the larynx, the sensory and motor nerves and their connection to the central nervous system, and the anatomy of the spinal cord. In his book ‘On the Affected Parts’ Galen states (V,1, 2): “The brain is the foremost source of sensitivity and motility for all parts of the body”.

The nerve supply to the larynx was revealed in extraordinary demonstrations in public, using vivisection in animals, with compression of the recurrent laryngeal nerves [27]: “For a demonstration, it is better to put the threads under the nerves without tying them. Then you can show that the animal cries out when struck, but that it suddenly becomes silent after the nerves have been tied. The spectators are astonished. They think it wonderful that voice is destroyed when small nerves... are tied. If you want to loosen them again to show that the animal recovers its voice – for this surprises the spectators even more – do not bind the loops too tightly so that it is easy to loosen them quickly” (AA 11 669; trans. [28]).

Galen’s experimental methodology in vivisection work on animal brains, together with his observations on brain injured patients, laid the groundwork for the modern concept of brain localisation and foreshadowed brain stimulation in awake craniotomy used today. Galen’s description of his experiments on the exposed animal brain is mesmerising [8].

“Should the dissection be thus performed, then after you have laid open the brain, and divested it of the dura mater, you can first of all press down on each of its four ventricles, and observe what derangements have affected the animal. I will describe to you what is always to be seen when you make this dissection, and also before it where the skull is perforated, as soon as one presses upon the brain with the instrument which the ancients call ‘the protector of the dura mater’. Should the brain be compressed on both the two anterior ventricles, then the degree of stupor which overcomes the animal is slight. Should it be compressed on the middle ventricle, then the stupor of the animal is heavier. And when one presses upon that ventricle which is found in the part of the brain lying at the nape of the neck, then the animal falls into a very heavy and pronounced

stupor. This is what happens also when you cut into the cerebral ventricles, except that if you cut into these ventricles, the animal does not revert to its natural condition as it does when you press upon them. Nevertheless it does sometimes do this if the incision should become united. This return to normal condition follows more easily, and more quickly, should the incision be made upon the two anterior ventricles. But if the incision encounters the middle ventricle, then the return to the normal comes to pass less easily and speedily. And if the incision should have been imposed upon the fourth, that is the posterior ventricle, then the animal seldom returns to its natural condition. Although, nevertheless if the incision should be made into this fourth ventricle, provided that you did not make the cut very extensive, that you proceed quickly, and that in the compression of the wound, in some way or other, you employ a certain amount of haste, the animal will revert to its normal state, since the pressure on the wound is then temporary only – and indeed especially in those regions where no portion of the brain overlies the ventricle, but where the meninx only is found. You then see how the animal blinks with its eyes, especially when you bring some object near to the eyes, even when you have exposed to view the posterior ventricle. Should you go towards the animal while it is in this condition, and should you press upon some one part of the two anterior ventricles, no matter which part it may be, in the place where as I stated the root of the two optic nerves lies, thereupon the animal ceases to blink with its two eyes, even when you bring some object near to the pupils, and the whole appearance of the eye on the side on which the ventricle of the brain upon which you are pressing becomes like the eyes of blind men” (AA 1X. 12; 18-19 DLT).

Conclusion

Galen lauded the tradition of medical and scientific explanation dating back to Hippocrates, Plato and Aristotle. He was a master rhetorician, combining the Platonic triad with the Aristotelian physic of four elements and humours, and produced the first coherent synthesis of structural and functional physiology. Galen’s encyclopaedic codifications integrated earlier knowledge and his teleological reasoning made his ideas attractive [6]. His achievements in anatomical science in antiquity are unequalled [8].

It can be argued that Galen’s dogmatic, didactic and pedantic style produced the effect of absolute certainty and authority that was desirable by the public and the medical profession. His explanations brought anatomy, logic and experience together [18]. There is no doubt he was a major force in medical thinking in his own time and a dominant influence for centuries after his death [1]. Certainly medical teaching was based on Galen’s works, both in Europe and the Arab world, for over a millennium [1]. As Porter states, Gaelic medicine was monumental which Galen intended it should be.

“I have done as much for medicine as Trajan did for the Roman Empire it is I and I alone, who have revealed the true path of medicine. It must be admitted that Hippocrates already staked out this path he prepared the way, but I have made it possible” ([18], primary source not cited).

Perhaps his most timeless treatises are those where he emphasises the importance of philosophy in medicine and, even today, his writings could be taken as a model of how fundamental theoretical

issues in medicine should be approached [1]. This remains of enduring relevance.

Galen brought neuroanatomical knowledge and physiology together in his study of the brain and nerves using experimental methodology which arguably represent the zenith of neurological investigation in the ancient world. His description of experiments on the exposed animal and animal brain is remarkable and, in my view, depicts the origins of experimental neurosurgery.

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