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Past and future aspects of clinical electrophysiology

There is no life without electricity

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Abstract

The diagnosis and treatment of clinical electrophysiology has a long and fascinating history. From the earliest time, no clinical symptom impressed the patient (and the physician) more than an irregular heart beat. Although ancient Chinese pulse theory laid the foundation for the study of arrhythmias and clinical electrophysiology in the 5th century BC, the most significant breakthrough in the identification and treatment of cardiac arrhythmias first occurred in this century. In the last decades, our knowledge of electrophysiology and pharmacology has increased exponentially. The enormous clinical significance of cardiac rhythm disturbances has favoured these advances. On the one hand, patients live longer and thus are more likely to experience arrhythmias. On the other hand, circulatory problems of the cardiac vessels have increased enormously, and this has been identified as the primary cause of cardiac rhythm disorders. Coronary heart disease has become not just the most significant disease of all, based on the statistics for cause of death. Arrhythmias are the main complication of ischemic heart disease, and they have been directly linked to the frequent arrhythmogenic sudden death syndrome, which is now presumed to be an avoidable "electrical accident" of the heart.

A retrospective look — often charming in its own right — may not only make it easier to sort through the copious details of this field and so become oriented in this universe of important and less important facts; it may also assist the observer in a chronological vantage point of the subject. The study of clinical electrophysiology is no dry compendium of facts and figures, but rather a dynamic field of study evolving out of the competition between various ideas, intentions and theories. (Cardiol J 2008; 15: 293–297)

Key words: history, electrophysiology, arrhythmias, pathophysiology, pacing

Introduction

The first physician and legendary founder of modern scientifically based medicine was Hippocrates. As the spiritual rector of the Hippocratic manuscript collection (*Corpus hippocraticum*), he gained paramount importance in the medical history of the West for establishing the medical professions tradition of education. As an "Asclepiad" and head of the School of Cos, he was thought to have been, according to tradition a 19th generation descendent of Asclepius the legendary god of medical science in Greek mythology [1].

Hippocrates stated in his Aphorisms (Section II, No. 41) "Those who are subject to frequent and severe fainting attacks without obvious cause die suddenly." (Fig. 1).

This might be the first description of sudden cardiac death. The Aphorism describes recurrent syncope in otherwise healthy individuals. These observations could be linked to electrical diseases as long QT syndrome, arrhythmogenic right ventricular

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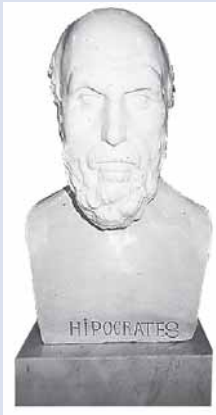
Table 1. Historical perspectives of clinical electrophysiology.

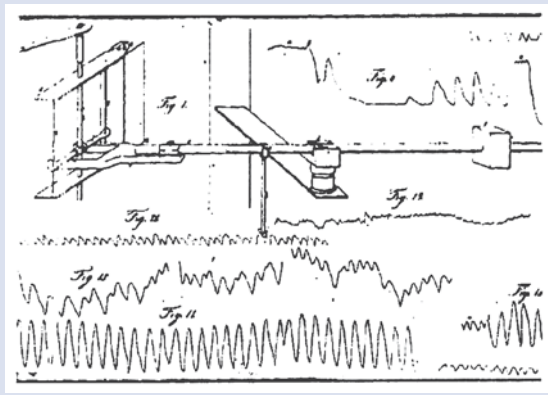
1580	Mercuriale G (1530–1606) — Ubi pulsus sit rarus semper expectanda est syncope [2]
1717	Gerbezius M (1658–1718) — Constitutio Anni 1717 a.A.D. Marco Gerbezio Labaco 10. Decem. descripta. Miscellanea Emphemerides Academiae Naturae [3]
1761	Morgagni GB (1682–1771) — De sedibus et causis morborum per anatomen indagatis [4]
1791	Galvani L (1737–1798) — De viribus electricitatis in motu musculari commentarius [5]
1800	Bichat MFX (1771–1802) — Recherches physiologiques sur la vie et la mort [6]
1804	Aldini G (1762–1834) — Theoretical and experimental essay on galvanism with a series of experiments conducted in the presence of representatives of the national Institute of France at various amphitheatres in London [7]
1827/1846	Adams R (1791–1875), Stokes W (1804–1878) — Cases of diseases of the heart accompanied with pathological observations; observations of some cases off a permanently slow pulse [8, 9]
1872	Duchenne de Bologne GBA (1806–1875) — On localized electrical stimulation and its pathological and therapeutic application by induced and galvanized current, both interrupted and continuous [10]
1882	von Ziemssen H (1829–1902) — Studies on the motions of the human heart as well as the mechanical and electrical excitability of the heart and phrenic nerve, observed in the case of the exposed heart of Catharina Serafin [11]
1890	Huchard H — La maladie de Adams-Stokes (Adams-Stokes syndrome)
1932	Hyan AS — Resuscitation of the stopped heart by intracardial therapy. II. Experimental use of an artificial pacemaker [12]
1952	Zoll PB — Resuscitation of the heart in ventricular standstill by external electrical stimulation [13]
1958	Elmquist R, Senning A — An implantable pacemaker for the heart [14]
1958	Furman S, Robinson G — The use of an intracardiac pacemaker in the correction of total heart block [15]
1961	Bouvrain Y, Zacouto F — L'entrainment èlectrosystolique du coeur [16]
1962	Lown B et al. — Bifocal demand pacing [17]
1969	Berkovits BV et al. — Bifocal demand pacing [18]
1972	Wellens HJJ et al. — Electrical stimulation of the heart in patients with ventricular tachycardia [19]
1975	Zipes DP et al. — Termination of ventricular fibrillation in dogs by depolarizing a critical amount of myocardium [20]
1978	Josephson ME et al. — Recurrent sustained ventricular tachycardia [21]
1980	Mirowski M et al. — Termination of malignant ventricular arrhythmias with an implanted automatic defibrillator in human beings [22]
1982	Gallagher JJ et al. — Catheter technique for closed-chest ablation of the atrioventricular conduction system: A therapeutic alternative for the treatment of refractory supraventricular tachycardia [23]
1982	Scheinman MM et al. — Transvenous catheter technique for induction of damage to the atrioventricular conduction system [24]
1982	Lüderitz B et al. — Therapeutic pacing in tachyarrhythmias by implanted pace-makers [25]
1985	Manz M et al. — Antitachycardia pacemaker (Tachylog) and automatic implantable defibrillator (AID): Combined use in ventricular tachyarrhythmias [26]
1987	Borggrefe M et al. — High frequency alternating current ablation of an accessory pathway in humans [27]
1988	Saksena S, Parsonnet V — Implantation of a cardioverter-defibrillator without thoracotomy using a triple electrode system [28]
1991	Jackman WM et al. — Catheter ablation of accessory atrioventricular pathways (Wolff-Parkinson-White syndrome) by radiofrequency current [29]
1991	Kuck KH et al. — Radiofrequency current catheter ablation of accessory path ways [30]
1994	Daubert C et al. — Permanent atrial resynchronisation by synchronous bi-atrial pacing in the preventive treatment of atrial flutter associated with high degree interatrial block [31]
1994	Cazeau S et al. — Four chamber pacing in dilated cardiomyopathy [32]
1994	Wiiffels MCEF et al. — Atrial fibrillation begets atrial fibrillation [33]
1995	Camm AJ et al. — Implantable atrial defibrillator [34]
1997	Jung W et al. — First worldwide implantation of an arrhythmia management system [35]
1998	Haissaguerre M et al. — Spontaneous initiation of atrial fibrillation by ectopic beats originating in the pulmonary veins [36]
1999	Josephson M et al. — Hybrid pharmacologic and ablative therapy: A novel and effective approach for the management of atrial fibrillation [37]
2006	Allessie MA — Mechanism of atrial fibrillation — an anatomical 3D Labyrinth of multiple narrow wavelets (World Congress of Cardiology, Barcelona, Spain) [38]
2007	Calkins HG et al. — HRS/EHRA/ECAS Consensus Statement on Atrial Fibrillation [39]



"Those who suffer from frequent and strong fainis without any manifest cause die suddenly.,,

Hippocrates (circa 466–377 BC)

Figure 1. Hippocrates from Cos.



Hoffa M, Ludwig C. Ztschrft Rat Med, 1850; 9: 107

Figure 2. First graphic documentation of ventricular fibrillation. In 1894, while investigating vagal influences on cardiac activity, M. Hoffa, in Carl Ludwig's laboratory, documented bizarre unregulated actions of the ventricles when exposed directly to strong faradic or constant currents. The disorder affected both rhythm and intensity, persisted after termination of electroexcitation and stopped cardiac output. The atria did not participate in the arrhythmia.

dysplasia (ARVD) and arrhythmogenic right ventricular cardiomyopathy (ARVC; Naxos disease), Brugada syndrome, hypertrophic cardiomyopathy etc.

Aside from the discovery of the cardiac conduction system and advancements in the electrotherapy of cardiac arrhythmias (Table 1) the development of electrocardiography was the key issue for a more detailed understanding of repolarization as a cause and a correlate of cardiac disorders particularly sudden death.

Carl Friedrich Wilhelm Ludwig (1816–1895) developed an instrument to record hemodynamic and other physiologic events accurately. For example, by simultaneously recording the pulse wave and respiratory pattern, he first described sinus arrhythmia in 1847. The first registration of ventricular fibrillation is depicted on Figure 2.

Waller's classic demonstration of the human ECG (called the electrocardiogram at the time already) from the intact human heart took place at St. Mary's Hospital, London, in May 1887, with surface electrodes strapped to the front and back of the chest. There were only two distorted deflections: ventricular depolarization and repolarization. The P-wave was not discernible with the 1887 apparatus. This historic event in 1887 was also witnessed by Einthoven. The following year, Waller recorded the ECG by using saline jars in which the extremities were immersed. Einthoven, himself, credited Waller with the first human ECG (Fig. 3) [1].

Whereas the qualitative and quantitative measurement of the pulse may be understood as a starting point in arrhythmia diagnoses, true understanding of cardiac rhythm disorders really began with electrocardiography using the string galvanometer refined by Einthoven [40].

Interventional electrophysiology

The invasive electrophysiologic diagnostic and stimulation procedure is a heart catheter technique based on the historical maneuver performed by Werner Forssmann. Following this pioneer, Scherlag and colleagues described the first intracardiac catheter recordings of the His bundle in 1969, whereas Dirk Durrer and Henrick J.J. Wellens were the first to execute programmed stimulation in man [41].

The programmed stimulation technique has in first-line been used to induce ventricular tachycardia and to elucidate the mechanisms of tachycardias in the Wolff-Parkinson-White syndrome. Electrophysiologic testing was then used more and more

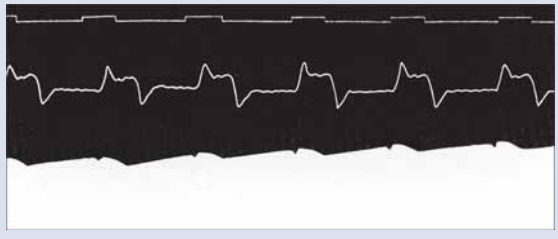


Figure 3. The first human electrocardiogram (ECG), recorded by Waller in 1897.

to guide pharmacological therapy and to delineate the electrophysiologic effects of drugs on the normal and diseased myocardium. The registration of the action potential in the experimental laboratory and in the intact human heart via catheter technique substantially changed our understanding about mechanisms in cellular depolarization and repolarization, antiarrhythmic drug effects and sudden cardiac death and arrhythmogenesis [42].

Torsade de pointes tachycardia

The typical arrhythmia of patients with congenital or acquired Long QT syndrome is the torsade de pointes tachycardia (TdP). This specific form of a dangerous polymorphic ventricular tachyarrhythmia is characterized by a repetitive change of the main QRS vector during tachycardia in the presence of a prolonged repolarization. François Dessertenne [43] first described the TdP morphology in an 80-year-old female patient with intermittent atrioventricular block (Fig. 4). The cause of her recurring syncopal episodes was the TdP tachycardia rather than the bradycardia, as it had primarily been suspected.

Coming back to Hippocrates, we can say, that he was the first to describe sudden cardiac death based on electrical diseases of the heart. Hippocrates' observations and intentions inspired experimental and clinical science to detect and to elaborate genetics, mechanisms, treatment and prevention of sudden death, one of the most important causes of mortality today (Table 2).

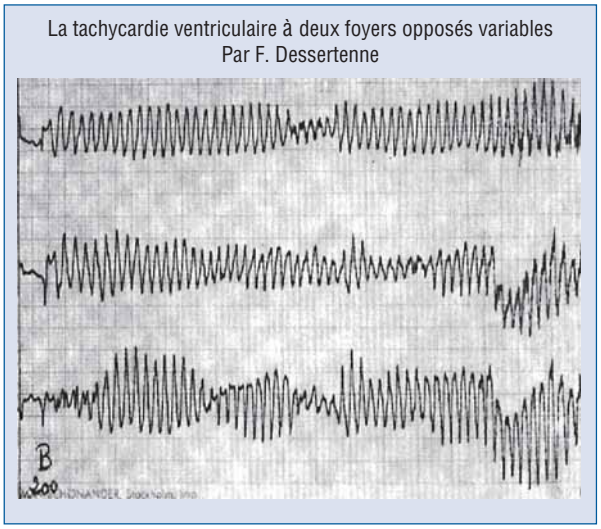


Figure 4. First description of torsade des pointes waves in 1966 by Dessertenne. He observed this rhythm disorder in an 80-year-old female patient with a complete intermittent atrioventricular block.

Table 2. Diseases likely to fit Hippocrates' aphorism.

Arrhythmogenic disease	Risk of SCD (% per year)	Genetic component?
Hypertrophic cardiomyopathy	1–4	+
Arrhythmogenic RV dysplasia	3	+
Dilated cardiomyopathy	4	+
Long QT syndrome	1–5	+
Wolff-Parkinson-White syndrome	0.15	+
Idiopathic ventricular tachycardia	High	Unknown
Brugada syndrome	10	+
Naxos disease (ARVC)	High	+

ARVC — arrhythmogenic right ventricular cardiomyopathy; RV — right ventricular; SCD — sudden cardiac death

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