



Trends in quantitative methods used for atrial fibrillation and ventricular tachycardia analyses



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ABSTRACT

Background: Improved quantitative and computational research efforts would be useful for better and more accurate analysis of heart arrhythmias, and to target catheter ablation sites. To pinpoint useful and leading-edge quantitative methods, research trends of articles published in peer-reviewed journals were identified.

Methods: The MEDLINE search tool and an in-house developed software program were used to detect quantitative trends in arrhythmia research. The main keywords used were ‘atrial fibrillation’ and ‘ventricular tachycardia’, which were searched in combination with commonly associated quantitative keywords for signal and imaging data. The search period used was 1960–2013. The linear regression trend over the search period was calculated, and the slope and regression coefficient was tabulated along with the onset year of the trend.

Results: In 1960, ‘atrial fibrillation’ and ‘ventricular tachycardia’ appeared in the title or abstract of less than 20 peer-reviewed articles each. A sharp increase in ventricular tachycardia publications occurred from 1975 to 1992 to a peak of over 600 publications; since 1992 the number of ventricular tachycardia studies has leveled. However, the number of atrial fibrillation papers has increased sharply since 1978, surpassing ventricular tachycardia studies in 1993, to over 3500 studies in 2013. From 1960 to 2013, the fraction of ventricular tachycardia papers associated with any particular quantitative keyword, versus the total number of ventricular tachycardia publications, was often greater than the fraction of atrial fibrillation papers associated with the same quantitative keyword, versus the total number of atrial fibrillation publications. Studies published in the bioengineering and bioinformatics literature comprise approximately 10% of all quantitative biomedical studies published on atrial fibrillation and ventricular tachycardia.

Conclusions: The MEDLINE search tool identified publication trends in quantitative arrhythmia research. Although ventricular tachycardia is a common ailment, as a quantitative research topic it appears only 20% as often as atrial fibrillation. Much of the quantitative ventricular tachycardia literature peaked in the 1990’s, while there is a continued sharp increase in atrial fibrillation research studies. This may have resulted from the publishing of seminal studies spurring interest in quantitative analysis of atrial fibrillation, versus the publishing of curative methods for treatment ventricular tachycardia, particularly during the period of approximately 1995–2000.

1. Introduction

Treatment of the most common cardiac arrhythmias, specifically atrial fibrillation (AF) and ventricular tachycardia (VT), is a subject of intense study, with treatment guidelines appearing in the medical literature being frequently updated [1,2]. For classification purposes, AF is generally categorized as either paroxysmal, longstanding persistent, and permanent [3], while VT is generally referred to and discerned as monomorphic or polymorphic [4]. Quantitative characteristics have been useful to distinguish the type of AF, and the transition from one type to another is likely indicative of a remodeling process in

the AF substrate over time [5–7]. Catheter ablation can improve outcome [8]. Likewise for VT, quantitative methods have been shown useful to discern monomorphic and polymorphic types [9], which is important to develop treatment options. Quantitative analysis of AF can be important to localize regions for substrate modification with the possibility of complete elimination of arrhythmogenic regions [7]. Quantitative methods for analysis of AF signals include the measurement of time series [8], spectral estimation [10], nonlinear methods [11], entropy [12], wavelet transformation [13], digital filtering [14], and eigenanalysis [15], as well as the use of multielectrode acquisition devices such as basket catheters [16]. Similarly, a variety of quantita-

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tive methods have been developed for signal analysis to distinguish the types and characteristics of VT [17,18] and for multielectrode recording of these arrhythmias [19]. All of these methods can be applied to image analysis in two dimensions, with the main imaging modalities used to quantitatively characterize these arrhythmias being magnetic resonance imaging (MRI), computerized tomography (CT), positron emission tomography (PET), and ultrasound.

There have been a number of seminal papers which have served to change the course of quantitative analysis and publication in the field of arrhythmia research. For AF studies, it was first suggested that AF causes electrophysiological changes of the atrial myocardium that could be responsible for the progressive nature of the arrhythmia in 1995 [20]. The time course for electrical remodeling of the substrate in AF was shown definitively in 1996 [21]. Treatment of a focal source of AF using radiofrequency ablation was done in 1997 [22]. The large risk of death for AF patients became of especial concern after the publication of the Framingham Heart Study [23]. The finding that ectopic beats originating from foci in the pulmonary veins leading to AF, which responds to radiofrequency ablation, was published in 1998 [24]. The use of circumferential radiofrequency ablation of pulmonary vein ostia to treat AF was published in 2000 [25]. Also in 2000, clinical outcomes were found to be improved for patients with refractory AF by using a combination of AV node ablation and permanent pacing therapy [26]. A meta-analysis was done to show the efficacy of antiarrhythmic drugs versus radiofrequency ablation in 2009, with the finding that there are advantages to radiofrequency ablation [27]. In basic science, the development of a new animal model of atrial fibrillation using chronic rapid atrial pacing was published in 1995 [28]. For VT studies, in 1995, epicardial mapping was achieved without complications [29]. In another study, published in 1997, electroanatomic mapping of the heart was enabled without fluoroscopy [30]. In the same year, 1997, the relationship between the thinnest infarct border zone and the isthmus of the reentrant circuit driving VT was shown [31]. Empirical antitachycardia pacing for fast VT was noted to be more efficacious than shocks from ICDs in 2004 [32].

The above studies suggest that in the mid 1990's and 2000's, new quantitative avenues and approaches for studying AF were developed, thus stimulating an interest in and possible increased volume of research and published contrast on this topic. The development of a number of curative therapies for VT during this same time period may have somewhat reduced interest and published quantitative research on this topic. However, postinfarction VT treatment with catheter ablation is sometimes difficult and research to better characterize the reentrant circuit is ongoing. In order to investigate these research topics further, in this study, the MEDLINE search tool was used to identify trends in the biomedical literature for the quantitative analysis of AF and VT. By identifying trends, it is possible to make inferences concerning the focus and direction of research in the field, so that the state of the art may be improved.

2. Method

In order to search for trends in quantitative arrhythmia research, the online MEDLINE database was used. The MEDLINE database works by determining the instance of a searched word in the title, abstract, and list of keywords of a paper. It searches for peer-reviewed papers with instances in all journals included in the MEDLINE database. The tool was used to search over successive years from 1960 to 2013. The last year was selected as 2013 because there is a delay to finalize the database after each year. AF and VT were searched using the terms 'atrial fibrillation' and 'ventricular tachycardia', respectively.

The following list was developed in part from a MEDLINE search of the most common quantitative terms associated with 'atrial fibrillation' and 'ventricular tachycardia', shown below in alphabetical order. There are associated keywords (40 in all), and their variants, used for identification purposes in this study:

activation or activity
 'body-surface' or 'body surface'
 catheter
 correlation
 CT or 'computed tomography'
 'dominant frequency'
 Doppler
 ECG or EKG or electrocardiogram
 eigen or eigenvector or eigenvalue or 'principal component' or 'principal components'
 electroanatomic
 'ensemble averaging' or 'ensemble average' or 'signal averaging' or 'signal average'
 entropy
 filter or filtered or filtering
 fractals or fractal or chaos or nonlinear or Lyapunov
 Fourier or fourier
 fractionated or fractionation
 'frequency analysis' or 'power spectrum'
 'f-wave' or 'F-wave' or 'f wave' or 'F wave'
 'high-density' or 'high density'
 intracardiac
 intramural
 lasso
 'linear prediction' or 'autoregressive moving average' or ARMA
 mapping or map or maps
 morphology
 MRI or 'magnetic resonance'
 PET or 'positron emission tomography'
 phase or phasic
 potential or voltage
 quantitative or quantitation
 regularity or organization or complexity
 similarity
 speckle
 'three-dimensional' or 'three dimensional' or 3D
 'time domain' or 'time series'
 transform
 'two-dimensional' or 'two dimensional' or 2D
 ultrasound or ultrasonography
 wave or wavefront or wavebreak
 wavelet or wavelets

Note that 'US' was not used as an abbreviation for 'ultrasound', as it is also used for other abbreviations in the medical literature.

To search for a keyword in association with AF for example, the following syntax was used –

'atrial fibrillation' and ('time series' or 'time domain').

When a keyword consisted of more than one word, it was bracketed by quotes, as shown above, which is required by the MEDLINE search tool. Multiple words were bracketed by parentheses. The logical 'or' was used to combine the occurrence of several variants of a keyword. For the example above,

'time series' or 'time domain'

were used to determine any and all research papers containing these keywords, which are two common ways to refer to the temporal analysis of the AF signal. The logical 'and' was used to determine those research papers in which at least one of the associated keywords appear in the literature with 'atrial fibrillation'. The process was repeated using the same keywords in association with 'ventricular tachycardia'. MEDLINE performs the search based upon words found in the Title, Abstract, and Keywords sections of the article.

The keywords for AF and VT were separately searched for the range in years 1960–2013 inclusive. The year 1960 was used as a starting point because it can be considered a watershed year for quantitative arrhythmia

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