Medical & Biological Engineering & Computing
https://doi.org/10.1007/s11517-023-02788-0

EDITORIAL

Together we are strong! Collaboration between clinicians and engineers as an enabler for better diagnosis and therapy of atrial arrhythmias

Axel Loewe[1] · **Armin Luik**[2] · **Roberto Sassi**[3] · **Pablo Laguna**[4,5]

The first electrocardiogram showing atrial fibrillation was published by Willem Einthoven already in 1906; also electrograms recorded within the atrial cavities in humans were described more than 70 years ago [1]. Since then, the marked improvements of early and accurate diagnosis of atrial arrhythmias, tailored treatment, and long-term success were in large parts driven by technological progress in signal acquisition and processing hardware as well as analysis algorithms in close interaction with clinical users and clinical studies evaluating outcome improvement. Olaf Dössel from Karlsruhe Institute of Technology (KIT) and Claus Schmitt from Städtisches Klinikum Karlsruhe established such close interaction between their teams and realized the synergistic potential very quickly. This essential role of close collaboration between engineers and clinicians, paired with the remaining great challenges, such as the treatment of persistent atrial fibrillation, led to the establishment of the Atrial Signals conference in 2015. After editions in Valencia and Bordeaux, Atrial Signals returned to Karlsruhe in autumn 2021 [2] with more than 70 oral presentations and panel discussions from leaders in the field, both clinical and technical. This event also marked the retirement of both Olaf Dössel and Claus Schmitt.

✉ Axel Loewe
axel.loewe@kit.edu

1 Institute of Biomedical Engineering, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

2 Medizinische Klinik IV, Städtisches Klinikum Karlsruhe, Karlsruhe, Germany

3 Università Degli Studi Di Milano, Milan, Italy

4 BSICoS Group, Aragón Institute of Engineering Research (I3A), University of Zaragoza, Zaragoza, Spain

5 Centro de Investigación Biomédica en Red en Bioingeniería, Biomateriales Y Nanomedicina (CIBER-BBN), Zaragoza, Spain

Olaf Dössel's innovations in the field of computational cardiology are numerous. In more than 25 years of research, his main contributions were in signal processing of electrograms and electrocardiograms [3], as well as in computational modeling and simulation of the heart with a particular focus on tissue level [4] and organ level/ECG applications [5]. He served on several editorial boards including this Journal, was president of the World Congress on Medical Physics and Biomedical Engineering in 2009, is a long-standing member of multiple academies of science, the board of directors of the Computing in Cardiology Conference, and a fellow of the International Union for Physical and Engineering Sciences in Medicine (IUPESM), the International Academy of Medical and Biological Engineering (IAMBE), the European Alliance of Medical and Biological Engineering and Science (EAMBES) and the German Society for Biomedical Engineering (DGBMT). Besides his direct scientific track record of several hundred publications, another important part of his legacy are more than 10,000 students that learned the basics of electrical engineering in his lectures and more than 60 early career researchers that completed a PhD under his guidance. The strong commitment and never-ending excitement to develop engineering approaches to a point where they can be applied in a clinical research setting paired with a lot of room to grow and develop for everyone is remarkable.

Claus Schmitt is a pioneer in invasive electrophysiology and cardiology. Inspired and shaped by a research fellowship in electrophysiology at the University of Pennsylvania under the direction of Marc E. Josephson in the late 1990s, he was captivated by the idea of understanding cardiac arrhythmias in detail and being able to cure them by catheter ablation. He was head of the electrophysiology department at the German Heart Center in Munich for more than 10 years and established the clinical electrophysiology as well as implantation of pacemakers and defibrillators there. He gained a significant international reputation through constant innovation and the use of new technologies up to the commissioning of one of the first stereotactic ablation systems worldwide. In more than one hundred publications, many congress papers, and several books, he openly addressed problems and challenges. He accompanied several randomized studies and was thus able to improve existing techniques. His educational books on intracardiac electrophysiology and catheter ablation of cardiac arrhythmias have guided generations of electrophysiologists during their training. However, his primary fascination from beginning to end was the ECG and the interpretation of intracardiac electrograms. With the move to Karlsruhe and the cooperation with Olaf Dössel, computer models and algorithms entered the electrophysiology laboratory and raised the interpretation of electrograms to a new level. With the common goal of developing an individualized approach for the treatment of atrial fibrillation, Claus Schmitt and Olaf Dössel started a unique close cooperation between clinicians and engineers. Claus Schmitt's never-ending drive to steadily improve methods and his courage to use them for the benefit of his patients, coupled with constant encouragement and challenge of individual team members is remarkable.

This special issue brings together seven articles summarizing some of the work presented at the fourth Atrial Signals conference in 2021 in Karlsruhe. Together with other recent special issues on atrial arrhythmias and technology for their diagnosis and treatment [6–8], they provide a good overview of the current state of the art and recent progress.

Two review articles summarize the state of the art, recent progress and open challenges in the fields of atrial conduction velocity mapping (Coveney et al. [9]) and application of electrocardiographic imaging (ECGI) in the atria (Hernández-Romero et al. [10]).

Five original articles present new methods, results and tools for better understanding, diagnosis, and treatment of atrial arrhythmias.

In a computational basic research study, Elliott et al. [11] investigate the effect of cellular heterogeneity on atrial repolarization and identified differences between the left and the right atrium. Riccio et al. [12] leverage multipolar electrograms to identify fibrotic atrial substrates based on dominant-to-remaining eigenvalues of unipolar electrograms of neighboring electrodes. After benchmarking their method on synthetic electrograms, they demonstrate feasibility in measured electrograms.

Heida et al. [13] use epicardial mapping data from 34 patients to better characterize the supervulnerable period after electrical cardioversion of atrial fibrillation. They found no significant differences in biatrial conduction differences between atrial fibrillation patients who were acutely cardioverted and those who already were in sinus rhythm for longer.

Dang et al. [14] use clinical data to correlate the information content of dominant frequency and slow conduction zone maps during atrial fibrillation. They found no significant correlation between the two types of maps in their cohort of 19 patients.

Finally, van Nieuwenhuyse et al. [15] present Directed-Graph-Mapping as a new tool to automatically analyze and characterize cardiac excitation patterns based on local activation time maps. They present a range of application scenarios including atrial tachycardia and fibrillation.

Despite the remarkable progress in the field of atrial arrhythmia diagnosis and treatment, many challenges remain open. Olaf Dössel and Claus Schmitt have demonstrated how close collaboration between engineers and clinicians can enable new solutions and their implementation. We believe that this example can be an excellent motivation and driver for future endeavors and we wish them all the best for their retirement.

Funding Open Access funding enabled and organized by Projekt DEAL.

References

1. Hecht HH (1946) Potential variations of the right auricular and ventricular cavities in man. Am Heart J 32:39–51. https://doi.org/10.1016/0002-8703(46)90225-6
2. Dössel O, Schmitt C, Unger LA, et al. (2021) Atrial signals 2021. Book of Abstracts. Karlsruhe Institute of Technology (KIT). https://doi.org/10.5445/IR/1000138445
3. Dössel O, Lenis G, Loewe A et al (2016) Model assisted biosignal analysis of atrial electrograms. Tm - Tech Mess 83:102–111. https://doi.org/10.1515/teme-2015-0122
4. Azzolin L, Eichenlaub M, Nagel C, et al. (2022) Personalized ablation vs. conventional ablation strategies to terminate atrial fibrillation and prevent recurrence. EP Eur euac 116. https://doi.org/10.1093/europace/euac116
5. Dössel O, Luongo G, Nagel C, Loewe A (2021) Computer modeling of the heart for ECG interpretation—a review. Hearts 2:350–368. https://doi.org/10.3390/hearts2030028

6. Berenfeld O, Corino VDA, Loewe A, et al. (2022) Editorial: atrial fibrillation: technology for diagnosis, monitoring, and treatment. Front Physiol 13:848096. https://doi.org/10.3389/fphys.2022.848096
7. Heijman J, Vernooy K, van Gelder IC (2021) The road goes ever on: innovations and paradigm shifts in atrial fibrillation management. EP Eur 23:ii1–ii3. https://doi.org/10.1093/europace/euab061
8. Ellinor PT (2020) Introduction to the compendium on atrial fibrillation, and a few thoughts along the way…. Circ Res 127:1–3. https://doi.org/10.1161/CIRCRESAHA.120.317516
9. Coveney S, Cantwell C, Roney C (2022) Atrial conduction velocity mapping: clinical tools, algorithms and approaches for understanding the arrhythmogenic substrate. Med Biol Eng Comput 60:2463–2478. https://doi.org/10.1007/s11517-022-02621-0
10. Hernández-Romero I, Molero R, Fambuena-Santos C et al (2022) Electrocardiographic imaging in the atria. Med Biol Eng Comput. https://doi.org/10.1007/s11517-022-02709-7
11. Elliott J, Mainardi L, Rodriguez Matas JF (2022) Cellular heterogeneity and repolarisation across the atria: an in silico study. Med Biol Eng Comput 60:3153–3168. https://doi.org/10.1007/s11517-022-02640-x
12. Riccio J, Alcaine A, Rocher S et al (2022) Atrial fibrosis identification with unipolar electrogram eigenvalue distribution analysis in multi-electrode arrays. Med Biol Eng Comput 60:3091–3112. https://doi.org/10.1007/s11517-022-02648-3
13. Heida A, van der Does WFB, van Schie MS et al (2022) Does conduction heterogeneity determine the supervulnerable period after atrial fibrillation? Med Biol Eng Comput. https://doi.org/10.1007/s11517-022-02679-w
14. Dang L, Angel N, Zhu M et al (2022) Correlation between conduction velocity and frequency analysis in patients with atrial fibrillation using high-density charge mapping. Med Biol Eng Comput 60:3081–3090. https://doi.org/10.1007/s11517-022-02659-0
15. Van Nieuwenhuyse E, Hendrickx S, den Abeele RV et al (2022) DG-Mapping: a novel software package for the analysis of any type of reentry and focal activation of simulated, experimental or clinical data of cardiac arrhythmia. Med Biol Eng Comput 60:1929–1945. https://doi.org/10.1007/s11517-022-02550-y

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Axel Loewe heads the Computational Cardiac Modeling Group at Karlsruhe Institute of Technology with a focus on cardiac electrophysiology and biomechanics. As a member of the faculty for Electrical Engineering and Communication Technology, he teaches biomedical engineering with a focus on modeling and signal processing.

After studying Electrical Engineering and Communication Technology in Karlsruhe and Stockholm, Axel received a Master of Science degree in 2013 and a PhD in 2016. His research won several prizes including the patient safety award. Axel is an active member of the scientific community with editorial contributions to many journals and responsibility for multiple international conferences and workshops. He is an IEEE Senior Member and published more than 160 articles in international journals and conferences in the fields of biomedical engineering, cardiology, physiology, applied mathematics and machine learning.

Armin Luik head the department of electrophysiology at the municipal hospital in Karlsruhe. He has a major interest in research on atrial arrhythmias. He is member of the German Society of Cardiology and the European Society for Cardiology. After finishing his medical degree he spend the beginning of his career in the German Heart Center in Munich and in 2007 stated his work in the Municipal hospital in Karlsruhe. Armin completed his state doctorate in 2018 at the university of Freiburg. He actively contributes to international research project and has close collaborations with several university and industry partners to advance the treatment and basic understanding of atrial arrhythmias. A large number of publications and active conference participations in the field of arrhythmia assessment, classification as well as new treatment technologies are proof of his continued work.

Roberto Sassi is Professor of Computer Science at the University of Milan, Italy, where he teaches courses on digital signal and image processing, and a master class on biomedical signal processing. He graduated in electronic engineering in 1996, and received a Ph.D. degree in biomedical engineering in 2001, both from Politecnico di Milano, Italy. He is the coordinator of the Ph.D. in Computer Science (2021–) and the director of the research group "Biomedical image and Signal Processing" (BiSP) at the University of Milan, where he supervised 8 Ph.D. students. He was a member of the board and has served as treasurer (2016–2021) of the Italian Gruppo Nazionale di Bioingegneria (GNB), he is an IEEE senior member (2012–) and a member of the e-Cardiology working group of the European Society of Cardiology, for which he participated in coordinating the development of the 2015 technical consensus document on heart rate variability. The research activity of Dr. Sassi has been mainly in the fields of biomedical signal and image processing, and applied mathematics. The methodological techniques have been exploited also to address related challenges in computer science, as biometrics, remote monitoring and healthy ageing. The results have been published in more than 150 publications in international journals and conferences.

Pablo Laguna received the M.Sc. and Ph.D. degrees in Physics from Zaragoza University, Zaragoza, Spain, in 1985 and 1990, respectively. He is Full Professor of Signal Processing and Communications in the Department of Electrical Engineering at the Engineering School, and researcher at the Aragon´ Institute for Engineering Research (I3A), both at Zaragoza University, Spain, where he was founder and responsible of the Master and Ph.D. programs in Biomedical Engineering (2003–2010 and 2005–2020, respectively), and is currently serving as director (2019–). He is member and has served as scientific director (2011–2015) of the Spanish Center for Biomedical Engineering, Biomaterial and Nano-medicine Research (CIBER-BBN). His professional research interests are in signal processing, in particular applied to biomedical applications. He has co-authored more than 180 research papers on this topic, over 300 international conference papers, and has advised 18 Ph.D. thesis. He has led a large number of projects on biomedical signal interpretation, especially in the cardiovascular domain, most of them with international collaborations at clinical and engineering sites. He has international scientific responsibilities such as editor of the journals Digital Signal Processing (EURASIP) and Medical and Biological Engineering and Computing (Springer), and has served as member and president on the Board of Directors of the Computing in Cardiology conference, organizer of different scientific conferences, etc. He is Fellow of the IEEE, EAMBES, and IAMBE. He is, together with L. Sornmo, the author of Bioelectrical Signal Processing in Cardiac and Neurological Applications, book (Elsevier, 2005).