Circulation: Arrhythmia and Electrophysiology

RESEARCH LETTER

Higher Daily Temperature Is Associated With Prolonged Device-Detected Atrial Fibrillation Episodes

Valentin Bilgeri, MD*; Philipp Spitaler, MD*; Patrick Rockenschaub, PhD*; Fabian Lehner, PhD; Lena Tschiderer, PhD; Fabian Barbieri, MD, PhD; Markus Stühlinger, MD; Bernhard Erich Pfeifer, PhD; Peter Willeit, PhD; Herbert Formayer, PhD; Axel Bauer, MD; Wolfgang Dichtl, MD

Weather extremes are increasingly recognized as cardiovascular risk factors, yet their effects on arrhythmia dynamics remain incompletely understood.[1,2] Atrial fibrillation (AF), the most common sustained arrhythmia, has known links to both cold and heat, but previous studies relied on episodic monitoring or hospital data, limiting temporal resolution.[3] We examined how ambient temperature and other weather conditions influence the onset and continuation of device-detected AF (DDAF) in patients with dual-chamber pacemakers capable of continuous rhythm monitoring.

Data were derived from the ongoing ACaSA (Pacemaker-based Long-term Monitoring of Sleep Apnea) study, a prospective cohort of patients with dual-chamber pacemakers (MicroPort CRM) implanted at the Medical University of Innsbruck, Austria. The study was approved by the institutional review board, and all participants provided written informed consent in accordance with the Declaration of Helsinki. Patients with preexisting permanent AF and follow-up <90 days were excluded from the analysis. Among 203 consecutively enrolled patients, we analyzed 112 355 patient-days between March 2022 and November 2024 with a median follow-up of 549 (interquartile range, 344–784) days. Weather data (temperature, relative humidity, precipitation, and air pressure change) were obtained from the Integrated Nowcasting through Comprehensive Analysis system at 1×1 km spatial resolution, matched to each patient's home municipality. DDAF was defined as ≥6 minutes of atrial high-rate episodes per day based on the pacemaker mode-switch algorithm. Days with AF burden shorter than 6 minutes were not counted to minimize false positives.

The primary end points were (1) DDAF onset (first day of an episode) and (2) DDAF continuation, defined as persistence of AF across midnight into the subsequent day, chosen over total episode duration or daily burden to better capture the dynamic effects of daily weather changes on arrhythmia persistence. A case-crossover design was applied using each patient as their own control, comparing meteorological conditions on days with and without AF. Conditional logistic regression with distributed lag nonlinear models was used to estimate associations between meteorological variables and AF outcomes, controlling for time-invariant confounding.

DDAF was detected in 114 patients (56.2%) over the study period, contributing to an overall of 4725 DDAF days. Median age was 75 (interquartile range, 68–80) years; 43% were female. At 10 °C maximum diurnal temperature, the chance of DDAF onset was lower than at 0 °C, with an odds ratio of 0.74 (95% CI, 0.60–0.92), meaning that higher temperatures were associated with a reduced risk (Figure, ①). Compared with a 100-Pa change (reference), higher air pressure changes of 300, 500, and 700 Pa were associated with progressively higher odds of DDAF onset, with odds ratios of 1.49 (95% CI, 1.08–2.06), 1.57 (95% CI, 1.19–2.06), and 1.86 (95% CI, 1.33–2.61), respectively. In contrast,

Key Words: air pressure ■ atrial fibrillation ■ cardiovascular diseases ■ pacemaker, artificial ■ weather

Correspondence to: Philipp Spitaler, MD, Department of Internal Medicine III, Medical University Innsbruck, Anichstraße 35, 6020 Innsbruck, Austria. Email philipp.spitaler@i-med.ac.at
*V. Bilgeri, P. Spitaler, and P. Rockenschaub contributed equally.
For Sources of Funding and Disclosures, see page 1111.
© 2025 American Heart Association, Inc.
Circulation: Arrhythmia and Electrophysiology is available at www.ahajournals.org/journal/circep

Nonstandard Abbreviations and Acronyms

AF	atrial fibrillation
DDAF	device-detected atrial fibrillation

compared with 0°C, higher temperatures of 30°C increased the odds of remaining in DDAF for another day 2.03-fold (95% CI, 1.30–3.16; Figure, ②). Lower relative humidity showed an association with decreased risk of DDAF continuation (odds ratio; *P*=0.018), whereas air pressure change (*P*=0.591) and precipitation (*P*=0.505) were not associated with DDAF continuation.

These findings suggest a bidirectional association of temperature with AF: cold conditions may increase vulnerability to AF initiation (confirming results already published in previous studies), while heat may facilitate its persistence. While mechanisms remain speculative, possible contributors include cold-induced sympathetic activation and vasoconstriction leading to atrial strain versus heat-related dehydration or electrolyte shifts promoting sustained arrhythmia.

Several limitations should be recognized. First, weather exposure was estimated based on home address; real-time patient location was not available, and indoor conditions were not measured. However, given the older age of the cohort and low prevalence of air conditioning in Austria (<10%), relevant exposure misclassification is unlikely and would bias results toward the null. Second, device data were summarized daily, precluding precise timing or circadian analysis of episodes. Third, almost all patients were of White ethnicity from a European alpine region, limiting generalizability. Notwithstanding, these results offer unique insights due to continuous, long-term rhythm monitoring and high-resolution environmental exposure data, supporting the hypothesis that ambient temperature is associated with both the initiation and duration of AF, thereby explaining seasonal patterns in AF burden and related outcomes. Importantly, these findings reflect observed associations, and causality cannot be determined. The data, analytic methods, and study materials are available upon reasonable request.

Further research is needed to explore underlying mechanisms and to assess whether these patterns are reproducible in other populations and climate zones. Studies incorporating wearable devices, real-time geolocation, and physiological monitoring may provide a more granular understanding of how climate and individual behavior interact with arrhythmia risk.

In conclusion, both cold and heat seem to be associated with AF in distinct ways. As climate variability increases, understanding the association of environmental factors with arrhythmia dynamics may become relevant for improving cardiovascular risk prediction and management.

ARTICLE INFORMATION

Affiliations

Department of Internal Medicine III (V.B., P.S., M.S., A.B., W.D.) and Institute of Clinical Epidemiology, Public Health, Health Economics, Medical Statistics & Informatics (P.R., L.T., P.W.), Medical University of Innsbruck, Austria. Institute of Meteorology and Climatology, BOKU University, Vienna, Austria (F.L., H.F.). Department of Cardiology, Angiology and Intensive Care, Deutsches Herzzentrum der Charité, Berlin, Germany (F.B.). Institute of Active Polymers and Berlin-Brandenburg Center for Regenerative Therapies, Helmholtz-Zentrum Hereon, Teltow, Germany (F.B.). Landesinstitut für integrierte Versorgung Tirol, Tirol Kliniken, Innsbruck, Austria (B.E.P.). Division for Digital Medicine and Telehealth, University for Health Sciences, Medical Informatics and Technology, Hall in Tirol, Austria (B.E.P.). Department of Public Health and Primary Care, University of Cambridge, United Kingdom (P.W.). Ignaz Semmelweis Institute, Interuniversity Institute for Infection Research, Vienna, Austria (P.W.).

Sources of Funding

The study was supported by an unrestricted educational grant from MicroPort CRM (Clamart, France).

Disclosures

None.

REFERENCES

1. Liu J, Varghese BM, Hansen A, Zhang Y, Driscoll T, Morgan G, Dear K, Gourley M, Capon A, Bi P. Heat exposure and cardiovascular health outcomes: a systematic review and meta-analysis. *Lancet Planet Health*. 2022;6:e484–e495. doi: 10.1016/S2542-5196(22)00117-6
2. Bell ML, Gasparrini A, Benjamin GC. Climate change, extreme heat, and health. *N Engl J Med*. 2024;390:1793–1801. doi: 10.1056/NEJMra2210769
3. Wass SY, Hahad O, Asad Z, Li S, Chung MK, Benjamin EJ, Nasir K, Rajagopalan S, Al-Kindi SG. Environmental exposome and atrial fibrillation: emerging evidence and future directions. *Circ Res*. 2024;134:1029–1045. doi: 10.1161/CIRCRESAHA.123.323477

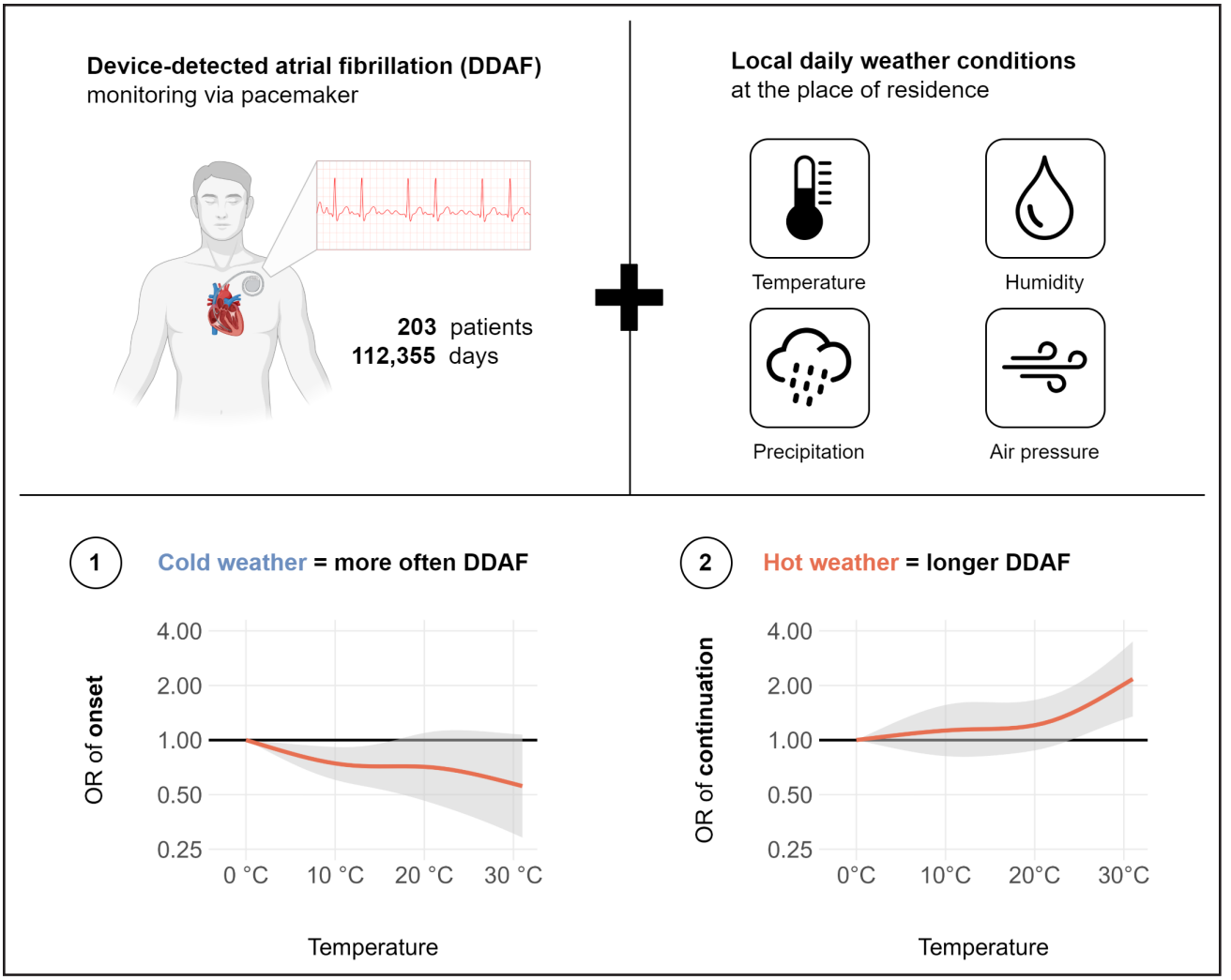


Figure. Bidirectional association of ambient temperature with atrial fibrillation dynamics.
The figure was created with BioRender. Bilgeri V. (2025) https://BioRender.com/1q7plal. OR indicates odds ratio.