MAYO CLINIC

MAYO CLINIC PROCEEDINGS:
INNOVATIONS, QUALITY & OUTCOMES

BRIEF REPORT

Daylight Saving Time Practice and the Rate of Adverse Cardiovascular Events in the United States: A Probabilistic Assessment in a Large Nationwide Study

Benjamin A. Satterfield, MD, PhD; Ozan Dikilitas, MD; Holly Van Houten, BA; Xiaoxi Yao, PhD, MPH; and Bernard J. Gersh, MBChB, DPhil

Abstract

We investigated the association of daylight saving time (DST) transitions with the rates of adverse cardiovascular events in a large, US-based nationwide study. The study cohort included 36,116,951 unique individuals from deidentified administrative claims data of the OptumLabs Data Warehouse. There were 74,722 total adverse cardiovascular events during DST transition and the control weeks (2 weeks before and after) in spring and autumn of 2015-2019. We used Bayesian hierarchical Poisson regression models to estimate event rate ratios representing the ratio of composite adverse cardiovascular event rates between DST transition and control weeks. There was an average increase of 3% (95% uncertainty interval, −3% to −10%) and 4% (95% uncertainty interval, −2% to −12%) in adverse cardiovascular event rates during Monday and Friday of the spring DST transition, respectively. The probability of this being associated with a moderate-to-large increase in the event rates (estimate event rate ratio, >1.10) was estimated to be less than 6% for Monday and Friday, and less than 1% for the remaining days. During autumn DST transition, the probability of any decrease in adverse cardiovascular event rates was estimated to be less than 46% and a moderate-to-large decrease in the event rates to be less than 4% across all days. Results were similar when adjusted by age. In conclusion, spring DST transition had a suggestive association with a minor increase in adverse cardiovascular event rates but with a very low estimated probability to be of clinical importance. Our findings suggest that DST transitions are unlikely to meaningfully impact the rate of cardiovascular events.

 ■ Mayo Clin Proc Inn Qual Out 2024;8(1):45-52

Daylight saving time (DST) is the practice of advancing clocks forward by 1 hour in spring and moving back by 1 hour in autumn for improved utilization of available daylight hours. Concerns have arisen whether DST practice leads to adverse health outcomes, such as cardiovascular events, due to circadian rhythm changes.

Previous studies have suggested modest associations between DST transitions and an increased incidence of ischemic stroke[1] and hospitalizations for atrial fibrillation.[2] In contrast, for acute myocardial infarction (AMI), the findings were inconsistent ranging from no association to small increases in AMI event rates in the spring and decreased rates in the autumn.[3-10] These studies were limited in sample size, geographical diversity, and the number of clinically relevant cardiovascular outcomes included as end points.

In this large-scale, US-based nationwide study, we sought to investigate the association of DST transitions with the rates of adverse cardiovascular events.

METHODS

Our study cohort was derived using deidentified administrative claims data from the OptumLabs Data Warehouse, which includes

From the Department of Cardiovascular Medicine (B.A.S., X.Y., B.J.G.) and Department of Internal Medicine (O.D.), Mayo Clinic, Rochester, MN; Robert D. and Patricia E. Kern Center for the Science of Health Care Delivery (H.V.H., X.Y.), Mayo Clinic, Rochester, MN; and OptumLabs (H.V.H.), Minnetonka, MN.

medical and pharmacy claims and enrollment records for commercial and Medicare Advantage enrollees. The database contains longitudinal health information on enrollees and patients, representing a diverse mixture of ages, ethnicities, and geographical regions across the United States.[11] The study population included adults (aged ≥18 years) with continuous medical insurance coverage during the intervention and control weeks within a 5-year timeframe (2015-2019). Residents of Arizona and Hawaii were excluded because these states do not observe DST. The intervention was defined as 1 week (Sunday to Saturday) after the DST transition. The control groups were defined across 4 weeks: pre #2, pre #1, post #1, and post #2, corresponding to 2 weeks before, 1 week before, 1 week after, and 2 weeks after the intervention week, respectively.

The outcome of interest, an adverse cardiovascular event, was defined as a composite of AMI, stroke, cardiogenic shock, cardiac arrest, and/or sudden death as the primary diagnosis during a hospitalization. Individual components of the composite outcome were ascertained using International Classification of Diseases Revision, 9th and 10th editions, diagnostic codes (Supplemental Table 1, available online at http://www.mcpiqojournal.org). The numbers of each component are summarized in the Table. If multiple events occurred during the same hospitalization, it was counted as a single event for analyses.

We used Bayesian hierarchical Poisson regression models to estimate the event rate ratios (ERRs) representing the ratio of events during the time of intervention in reference to control timeframe as defined earlier. Both the intercept and the slope (logarithm of ERR) were allowed to vary across 3 levels (study year, week, and day) and modeled to be correlated within these levels. We used weakly informative priors so that the inference was predominantly driven by the observed data. This was done for the entire cohort for the primary analyses and subgroup analyses based on the following age groups: 18-64 years, 65-74 years, and older than 75 years.

Specifically, we used the following regression models to estimate the ERR:

$$\beta_{intercept} \sim \mathbf{Normal}(\mathbf{0}, \mathbf{10})$$

$$\beta_{DST} \sim \mathbf{Normal}(\mathbf{0}, \mathbf{2.5})$$

$$\sigma_{year} \sim \mathbf{Exponential}(\mathbf{1})$$

$$\sigma_{week} \sim \mathbf{Exponential}(\mathbf{1})$$

$$\sigma_{day} \sim \mathbf{Exponential}(\mathbf{1})$$

$$\Omega_{year} \sim \mathbf{LKJ}(\mathbf{2})$$

$$\Omega_{week} \sim \mathbf{LKJ}(\mathbf{2})$$

$$\Omega_{day} \sim \mathbf{LKJ}(\mathbf{2})$$

$$b_{year} \sim \textbf{Multivariate Normal}\left(\begin{bmatrix}\mathbf{0}\\ \mathbf{0}\end{bmatrix}, \mathrm{diag}(\sigma_{year})\Omega_{year}\,\mathrm{diag}(\sigma_{year})\right)$$

$$b_{week} \sim \textbf{Multivariate Normal}\left(\begin{bmatrix}\mathbf{0}\\ \mathbf{0}\end{bmatrix}, \mathrm{diag}(\sigma_{week})\Omega_{week}\,\mathrm{diag}(\sigma_{week})\right)$$

$$b_{day} \sim \textbf{Multivariate Normal}\left(\begin{bmatrix}\mathbf{0}\\ \mathbf{0}\end{bmatrix}, \mathrm{diag}(\sigma_{day})\Omega_{day}\,\mathrm{diag}(\sigma_{day})\right)$$

where β denotes the mean effect for the intercept and the slope representing the logarithms of the mean event rate and ERR, respectively; b indicates a vector of deviations in the intercept and the slope in each respective group level (ie, year, week, and day); σ denotes a vector of standard deviations of b for each group level; and lastly, Ω represents the correlation matrix for b (ie, for the intercept and the slope) separately in each corresponding group level where diag denotes the diagonal matrix and $\mathrm{diag}(\sigma)\Omega\mathrm{diag}(\sigma)$ equals to the unstructured variance covariance matrix Σ. Finally, the model likelihood for the observed event counts is specified as follows:

$$count_{event} \sim \mathbf{P}\mathrm{oisson}\left(\exp\left(\mathrm{X}\beta + Z_{year}\, b_{year} + Z_{week}\, b_{week} + Z_{day}\, + b_{day}\right)\right)$$

Mayo Clin Proc Inn Qual Out ■ February 2024;8(1):45-52 ■ https://doi.org/10.1016/j.mayocpiqo.2023.12.006
www.mcpiqojournal.org

TABLE. Event Rates for Each Component of the Composite Cardiovascular Events by Daylight Saving Time Transition Period[a]

Cardiovascular event type	2015		2016		2017		2018		2019		Total
	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	
AMI	2653	2712	3281	3364	3911	3838	4038	4031	4284	4030	36,142
Stroke	2443	2313	3056	3020	3644	3628	3944	3841	4265	4044	34,198
Cardiac arrest	534	432	716	605	810	666	820	730	868	736	6917
Cardiogenic shock	[b]	[b]	15	15	12	15	16	20	20	18	147
Sudden death	16	12	19	11	17	14	19	17	11	14	150

[a]AMI, acute myocardial infarction.
[b]Events less than 11 were suppressed to protect patient confidentiality, but total for the year 2015 was 16.

where X denotes the design matrix for the intercept and the intervention (ie, DST transition), and Z represents the design matrices indicating the corresponding year, week, and day for the event count, and exp is the exponential function.

We derived the posterior distributions of ERR per each day of the week by marginalizing out (ie, averaging out) the effects of the control weeks and the study years using the joint posterior distribution. Posterior distributions can be interpreted as probability of different effect sizes given our observed data, prior distributions, and model structure. These distributions can be used to summarize the most likely values of a quantity of interest (eg, 95% uncertainty interval for ERR based on the full posterior distribution) or used to make probabilistic statements to assert the probability of whether this quantity is in a range of interest (eg, probability of ERR, >1.1, corresponding to a 10% increase in event rates).

Bayesian models were generated and fitted using the R package brms, version 2.18.0, cmdstan, version 2.30.1, and R version 4.2.3. In brief, brms uses Stan probabilistic programming language as its backend to perform Bayesian analyses, which uses No-U-Turn-Sampler, an adaptive form of Hamiltonian Monte Carlo sampling, to estimate posterior probability distributions for model parameters given prior distributions and model likelihood. Model design and correlation matrices underwent QR and Cholesky decompositions, respectively, to improve sampling efficiency and numerical stability. For all models, 4 Markov chains were used with each running for 6000 iterations (initial 3000 iterations discarded as warmup). Model fit and convergence were assessed with the evaluation of trace plots of Markov chains, $\widehat{R}$ values and effective sample sizes for all model parameters, confirming absence of any divergent transitions, and graphical posterior predictive checks.

RESULTS

Between 2015 and 2019, claims data for 36,116,951 unique individuals (Supplemental Table 2, available online at http://www.mcpiqojournal.org) were examined with a cumulative count of 74,722 cardiovascular events (Supplemental Table 3, available online at http://www.mcpiqojournal.org). After the spring DST transition, we noted a small increase in the mean number of adverse cardiovascular events on Monday and Friday compared with that in control weeks (ERR [95% uncertainty interval]: Monday, 1.03 [0.97-1.10]; Friday, 1.04 [0.98-1.12]). The probability of any increase in the ERR in the intervention week compared with that in control weeks (ie, ERR, >1.0) was 81.2% for Monday, 87.8% for Friday, and less than 60% for all other days. However, the probability of this being moderate-to-large in size (ie, ERR, >1.1; >10% increase in the rate of adverse events) was 3.1% for Monday, 5.7% for Friday, and less than 1% for the remaining days (Figure 1A). When this marginalized effect (ie, averaged out across control weeks) was evaluated for each different control week, the pattern was similar (Figure 2A).

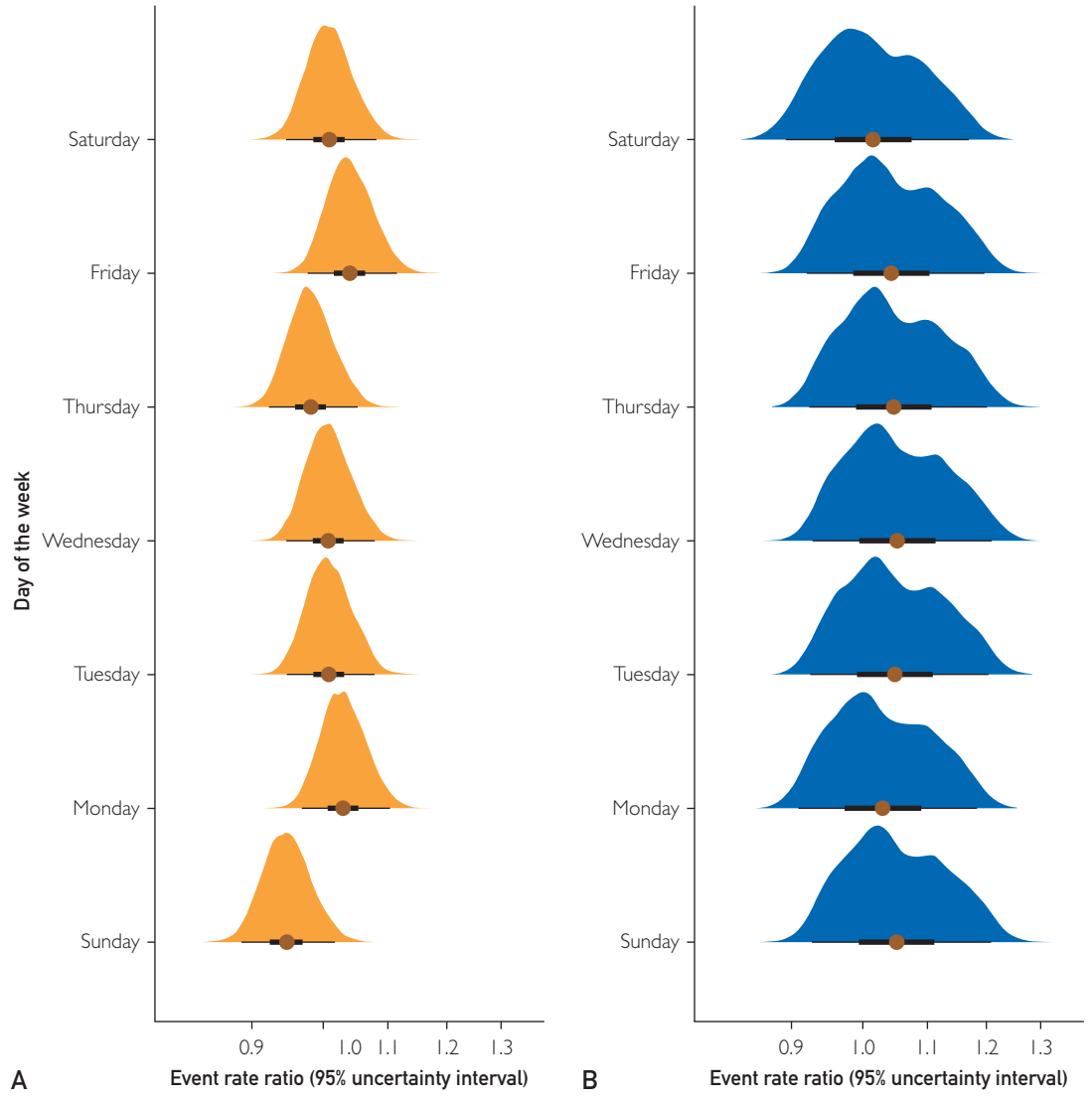

FIGURE 1. Orange and blue density plots denote full posterior distributions of event rate ratios for adverse cardiovascular events during daylight saving time transitions in (A) spring and (B) autumn, respectively, where day level results were obtained by marginalizing out week and year level effects from the joint posterior distribution. Black dots represent posterior mean event rate ratios, whereas thick and thin black horizontal lines denote 50% and 95% uncertainty intervals, respectively.

During autumn, the mean number of adverse cardiovascular events was modestly increased across all days during the intervention week compared with that in control weeks, where posterior mean ERRs ranged between 1.01 and 1.05. However, the probability of the adverse cardiovascular event rates to be higher during the intervention week than those during control weeks was less than 73%, whereas a moderate-to-large difference was less than 30% across all days of the week (Figure 1B). Given inconsistent prior reports of decreased cardiovascular events rates after autumn DST transition, we also estimated the probability of this phenomenon in this study. After autumn DST transition, the probability of any decrease in adverse cardiovascular event rates was estimated to be less than

Mayo Clin Proc Inn Qual Out ■ February 2024;8(1):45-52 ■ https://doi.org/10.1016/j.mayocpiqo.2023.12.006
www.mcpiqojournal.org

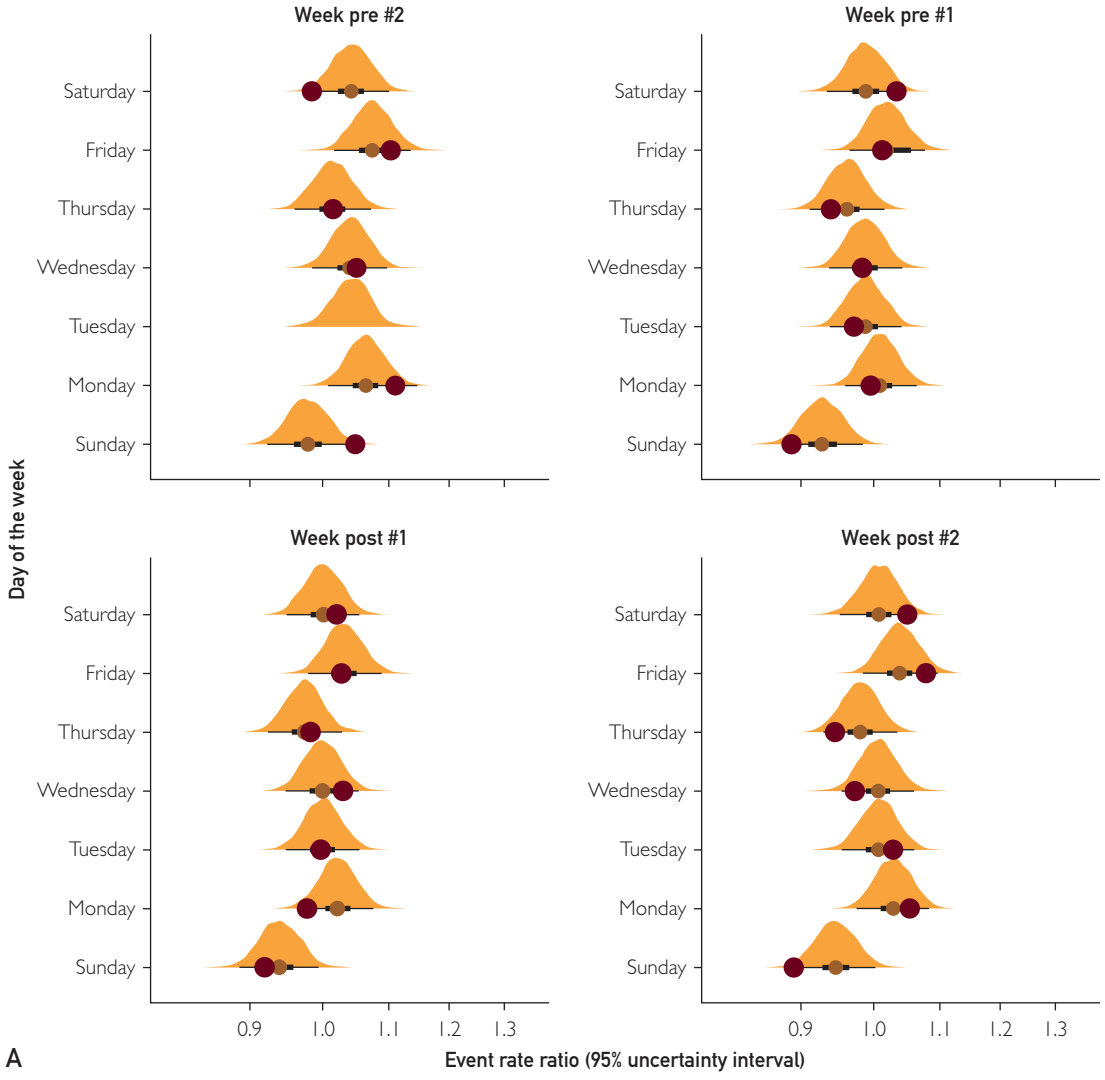

FIGURE 2. Orange and blue density plots denote full posterior distributions of event rate ratios (ERRs) for adverse cardiovascular events during daylight saving time transitions in (A) spring and (B) autumn, respectively, where day and week level results were obtained by marginalizing out year level effects from the joint posterior distribution. Black dots represent posterior mean ERRs, whereas thick and thin black horizontal lines denote 50% and 95% uncertainty intervals, respectively. Light purple dots denote observed ERR values computed by the ratio of raw event counts (averaged over study years) in the week of daylight saving time change and the respective control day-week combination.

46%, whereas a moderate-to-large decrease in the event rates (ie, ERR, <0.9; >10% decrease) was estimated to be less than 4% across all days of the week. The probabilities for each day of the week are given in Supplemental Table 4 (available online at http://www.mcpiqojournal.org).

Because cardiovascular event rates are known to increase with age, we performed subgroup analyses based on age with similar results to the primary analyses (Supplemental Table 5, available online at http://www.mcpiqojournal.org).

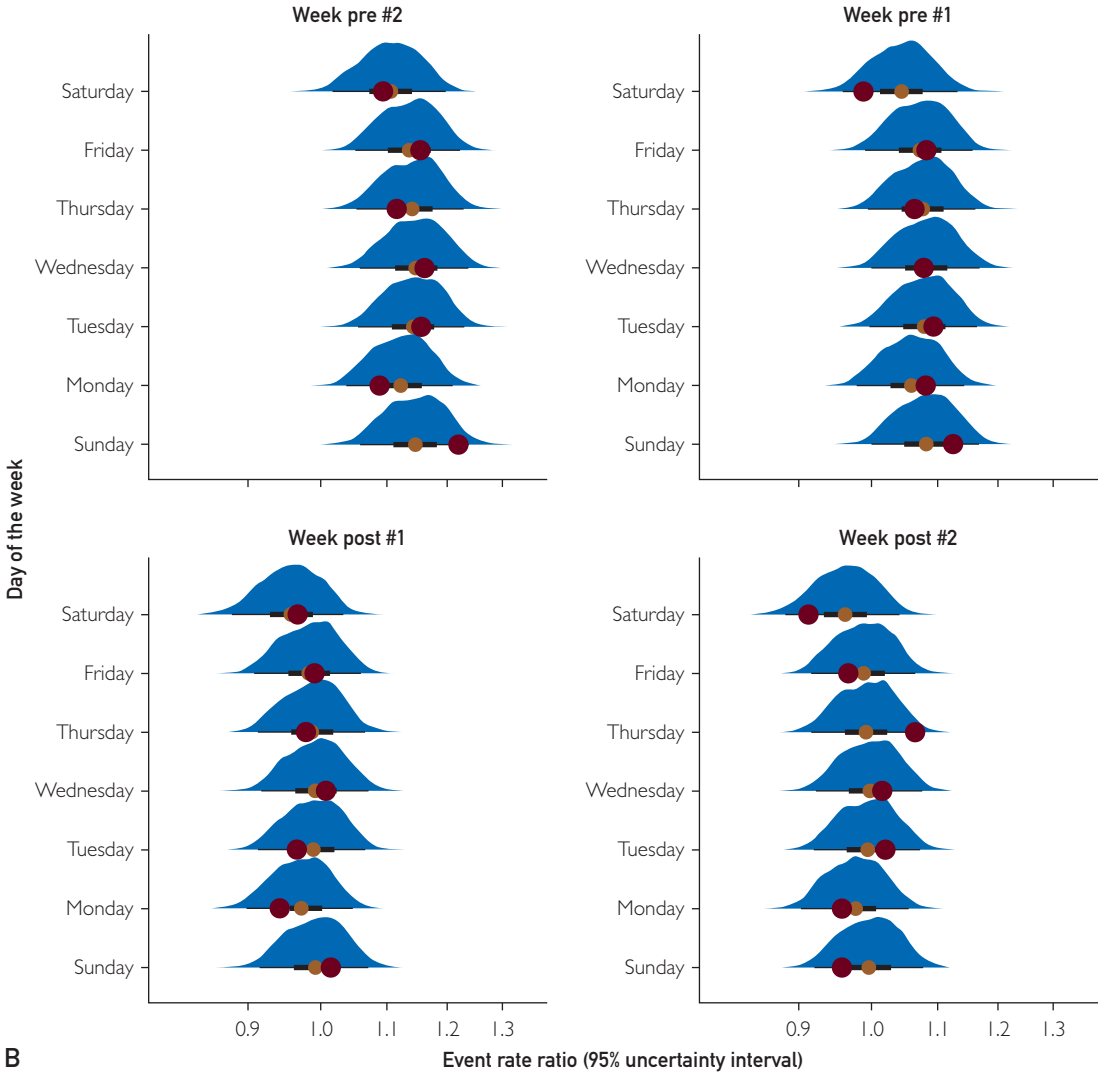

FIGURE 2. (*continued*).

The posterior distributions for ERR in autumn were bimodal as shown in Figure 1B, prompting us to further investigate whether ERRs had a variable pattern among different control weeks. The estimated ERR progressively decreased from control week pre #2 to week post #2 (Figure 2B), indicating a relatively lower number of adverse cardiovascular events during the 2 controls weeks leading up to the DST transition and similar event rates during the intervention week and the following 2 control weeks.

DISCUSSION

In this large, nationwide US-based cohort, we found evidence suggestive of a limited increase in adverse cardiovascular events, primarily characterized by AMI and stroke, after the spring DST transition. However, we found low likelihood of a substantial change in the

Mayo Clin Proc Inn Qual Out ■ February 2024;8(1):45-52 ■ https://doi.org/10.1016/j.mayocpiqo.2023.12.006
www.mcpiqojournal.org

rates of adverse events exceeding 10% during either of the seasonal DST transitions. These results collectively suggest that the practice of DST is unlikely to have a clinically meaningful association with cardiovascular events in the general population.

Our study has several notable strengths. First, we used a hierarchical structure across study years, control weeks, and days to model the adverse event counts, thereby producing more reliable estimates for average ERRs after DST transition. Second, our analyses were probabilistic in nature, enabling us to both determine the probability of any change in adverse cardiovascular event rates after DST transition and assess the likelihood of this effect being of clinically meaningful magnitude. Finally, by using claims data from diverse regions across the United States, our patient population size and the degree of generalizability surpassed that of most previous studies.

Because this is a cross-sectional study, it is limited in its ability to understand outcomes over time. Our data are retrospective and were obtained by insurance claims data with billing codes, and individual chart review was not performed to confirm diagnoses. This study included data only from the United States. Prior patient risk factors and comorbidities were not fully available, and this study was not designed to selectively look at patients at particularly high risk of cardiovascular event; rather, the general population was examined. It is possible that certain subpopulations may be at particular risk for DST transitions that are not specifically examined in this study.

DST practice was intended to align social and work activities with daylight hours and to conserve energy via less artificial lighting,[12] although whether this has been achieved lacks strong evidence. Simulation and observational studies suggest that the reduced energy need for artificial lighting is offset by increased energy demand for heating, cooling, and added social cost of pollution emissions.[12-14] Furthermore, concerns have arisen whether DST practice leads to adverse health outcomes, specifically cardiovascular, due to circadian rhythm changes. The initial evidence suggesting a small changes in AMI incidence ratios after DST transitions[3] was not consistently replicated in subsequent studies.[3,6,8,10] This prompted additional studies using more sophisticated statistical models adjusting for confounders and reporting inconsistent changes in event rates such as only occurring on certain days, subpopulations, or not detected at all.[4,5,7,9,15]

The decision to continue DST practice is both controversial and complex, requiring careful consideration of a variety of factors such as its impact on energy use, social and economic implications, and health outcomes. Based on the prior reports, in conjunction with our findings, DST transitions in the spring and autumn are unlikely to have a prominent impact on the rate of cardiovascular events in the United States. The impact of DST on other medical conditions (such as stroke,[1] atrial fibrillation,[2] depression,[16] and immune-related disorders[4]) and other factors (accidental deaths[17] and motor vehicle accidents[18]) should be considered for discussions regarding policy change for DST implementation.

CONCLUSION

Spring DST transition had a suggestive association with a minor increase in adverse cardiovascular event rates during Monday and Friday in the week following the transition. The probability of this association to be of clinically meaningful magnitude was estimated to be very low. There was no evidence suggestive of a meaningful change in the adverse cardiovascular event rates after autumn DST transition. Taken together, our findings suggest that DST transitions are unlikely to be associated with a marked increase in adverse cardiovascular events.

POTENTIAL COMPETING INTERESTS

Dr Satterfield reports patent 20110045468—polynucleotides for the identification and quantification of group A Streptococcus nucleic acids. The other authors report no competing interests.

ACKNOWLEDGMENTS

Drs Satterfield and Dikilitas contributed equally as first authors.

SUPPLEMENTAL ONLINE MATERIAL

Supplemental material can be found online at http://www.mcpiqojournal.org. Supplemental material attached to journal articles has not been edited, and the authors take responsibility for the accuracy of all data.

Abbreviations and Acronyms: **AMI,** acute myocardial infarction; **DST,** daylight saving time; **ERR,** event rate ratio

Grant support: This study was funded by Mayo Clinic Robert D. and Patricia E. Kern Center for the Science of Health Care Delivery. No extramural funding was used to support this work. The authors are solely responsible for the design and conduct of this study, all study analyses, the drafting and editing of the paper, and its final contents.

Data Previously Presented: Data from this manuscript were presented at the 2023 American Heart Association National meeting in Philadelphia, PA.

Correspondence: Address to Benjamin A. Satterfield, MD, PhD, Department of Cardiovascular Medicine, Mayo Clinic, 200 First Street SW, Rochester, MN 55905 (satterfield.benjamin@mayo.edu).

ORCID

Benjamin A. Satterfield: https://orcid.org/0000-0002-7798-0938

REFERENCES

1. Sipilä JO, Ruuskanen JO, Rautava P, Kytö V. Changes in ischemic stroke occurrence following daylight saving time transitions. *Sleep Med*. 2016;27(1):20-24. https://doi.org/10.1016/j.sleep.2016.10.009.
2. Chudow JJ, Dreyfus I, Zaremski L, et al. Changes in atrial fibrillation admissions following daylight saving time transitions. *Sleep Med*. 2020;69(1):155-158. https://doi.org/10.1016/j.sleep.2020.01.018.
3. Janszky I, Ljung R. Shifts to and from daylight saving time and incidence of myocardial infarction. *N Engl J Med*. 2008;359(18):1966-1968. https://doi.org/10.1056/NEJMc0807104.
4. Zhang H, Dahlén T, Khan A, Edgren G, Rzhetsky A. Measurable health effects associated with the daylight saving time shift. *PLoS Comput Biol*. 2020;16(6):e1007927. https://doi.org/10.1371/journal.pcbi.1007927.
5. Sandhu A, Seth M, Gurm HS. Daylight savings time and myocardial infarction. *Open Heart*. 2014;1(1):e000019. https://doi.org/10.1136/openhrt-2013-000019.
6. Jiddou MR, Pica M, Boura J, Qu L, Franklin BA. Incidence of myocardial infarction with shifts to and from daylight savings time. *Am J Cardiol*. 2013;111(5):631-635. https://doi.org/10.1016/j.amjcard.2012.11.010.
7. Kirchberger I, Wolf K, Heier M, et al. Are daylight saving time transitions associated with changes in myocardial infarction incidence? Results from the German MONICA/KORA Myocardial Infarction Registry. *BMC Public Health*. 2015;15(1):778. https://doi.org/10.1186/s12889-015-2124-4.
8. Sipilä JO, Rautava P, Kytö V. Association of daylight saving time transitions with incidence and in-hospital mortality of myocardial infarction in Finland. *Ann Med*. 2016;48(1-2):10-16. https://doi.org/10.3109/07853890.2015.1119302.
9. Čulić V. Daylight saving time transitions and acute myocardial infarction. *Chronobiol Int*. 2013;30(5):662-668. https://doi.org/10.3109/07420528.2013.775144.
10. Janszky I, Ahnve S, Ljung R, et al. Daylight saving time shifts and incidence of acute myocardial infarction—Swedish Register of Information and Knowledge About Swedish Heart Intensive Care Admissions (RIKS-HIA). *Sleep Med*. 2012;13(3):237-242. https://doi.org/10.1016/j.sleep.2011.07.019.
11. Wallace PJ, Shah ND, Dennen T, Bleicher PA, Crown WH. Optum Labs: building a novel node in the learning health care system. *Health Aff (Millwood)*. 2014;33(7):1187-1194. https://doi.org/10.1377/hlthaff.2014.0038.
12. Stražišar BG, Stražišar L. Daylight saving time: pros and cons. *Sleep Med Clin*. 2021;16(3):523-531. https://doi.org/10.1016/j.jsmc.2021.05.007.
13. Kotchen MJ, Grant LE. Does daylight saving time save energy? Evidence from a natural experiment in Indiana. *Rev Econ Stat*. 2011;93(4):1172-1185. https://doi.org/10.1162/REST_a_00131.
14. Hill SI, Desobry F, Garnsey EW, Chong YF. The impact on energy consumption of daylight saving clock changes. *Energy Policy*. 2010;38(9):4955-4965. https://doi.org/10.1016/j.enpol.2010.03.079.
15. Manfredini R, Fabbian F, Cappadona R, et al. Daylight saving time and acute myocardial infarction: a meta-analysis. *J Clin Med*. 2019;8(3):404. https://doi.org/10.3390/jcm8030404.
16. Wise J. Daylight saving is linked to depression, Danish study finds. *BMJ*. 2016;355(1):i5857. https://doi.org/10.1136/bmj.i5857.
17. Varughese J, Allen RP. Fatal accidents following changes in daylight savings time: the American experience. *Sleep Med*. 2001;2(1):31-36. https://doi.org/10.1016/s1389-9457(00)00032-0.
18. Fritz J, VoPham T, Wright KP Jr, Vetter C. A chronobiological evaluation of the acute effects of daylight saving time on traffic accident risk. *Curr Biol*. 2020;30(4):729-735.e2.