Increased Patient Safety-Related Incidents Following the Transition into Daylight Savings Time

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BACKGROUND: "Spring forward," the start of daylight savings time (DST), reduces sleep opportunity by an hour. Insufficient sleep in healthcare workers resulting from the spring forward time change could potentially result in an increase in medical errors.
OBJECTIVE: We examined the change in reported patient safety-related incidents (SRIs), in the week following the transition into and out of DST over a period of 8 years.
DESIGN: Observational study
SETTING: A US-based large healthcare organization with sites across multiple states
MEASUREMENTS: Voluntarily reported SRIs that occurred 7 days prior to and following the spring and fall time changes for years 2010–2017 were ascertained. SRIs likely resulting from human error were identified separately. The changes in the number of SRIs (either all SRIs or SRIs restricted to those likely resulting from human error) from the week before and after the time change (either spring or fall) were modeled using a negative binomial mixed model with a random effect to correct for non-independent observations in consecutive weeks.
RESULTS: Over the 8-year period, we observed 4.2% (95% CI: − 1.1 to 9.7%; $p = 0.12$) and 8.8% (95% CI: − 2.5 to 21.5%; $p = 0.13$) increases in overall SRIs in the 7 days following DST when compared with 7 days prior for spring and fall, respectively. By restricting to SRIs likely resulting from human errors, we observed 18.7% (95% CI: 5.6 to 33.6%; $p = 0.004$) and 4.9% (95% CI: − 1.3 to 11.5%; $p = 0.12$) increases for spring and fall, respectively.
CONCLUSION: Policy makers and healthcare organizations should evaluate delayed start of shifts or other contingency measures to mitigate the increased risk of SRIs during transition to DST in spring.

KEY WORDS: medical error; patient safety; spring forward; sleep deprivation

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INTRODUCTION

Sleep deprivation results in a slowing of response speed and reduces alertness and vigilance.[1] Partial sleep deprivation resulting from reduced total sleep time over a 24-h period is associated with greater cognitive and motor impairment as compared with long-term sleep deprivation.[2] Sleep disruption also decreases sustained attention and increases the risk of errors.[3] In addition, cognitive performance is impaired for 20–120 min immediately following awakening secondary to sleep inertia.[4] The effects of sleep deprivation and sleep inertia-related impairment on cognitive performance, alertness, and attention are particularly concerning in healthcare workers where sleep deprivation has been shown to be associated with an increased risk of medical errors.[5–8]

Every year, the "spring forward" transition into daylight savings time (DST) reduces sleep opportunity by an hour. Moving clocks forward following the spring forward results in a reduction in the total sleep time.[9,10] Among healthcare workers, this reduced total sleep and associated partial sleep deprivation resulting from the spring forward time change could potentially result in an increase in medical errors.[6–8] Additionally, with the change in time, healthcare workers report to and commence work at a start time that is earlier than usual while likely still experiencing cognitive impairment secondary to sleep inertia.

The impact of sleep deprivation resulting from the spring forward time change on medical errors has not been explored previously. An increase in medical errors following this time change would suggest that there are potentially modifiable risk factors that could help mitigate patient risk. In this study, we examined the change in all voluntarily reported patient safety-related incidents (SRIs), which include near-misses or adverse events, in the week following the transition into DST over a period of 8 years from a single large healthcare organization. SRIs specifically resulting from human error were identified and analyzed separately. In addition, the changes in all SRIs and human error-related SRIs occurring following that transition out of DST in the fall were also examined to serve as a comparator.

METHODS

Voluntarily reported SRIs that occurred 7 days prior to and following the spring and fall time changes for years 2010–2017 in a large healthcare organization including sites in multiple states were ascertained. As part of a commitment to safety, all healthcare workers in the organization are encouraged to voluntarily report any event, incident, or condition that could result or did result in patient harm (SRI) (Box 1). The report is electronically logged and details including the time of the event, location, patient record number, and the category of the event are manually entered. The term healthcare worker in this study refers to all employees of the organization involved in any patient care, direct or indirect. Data from all sites located in states that implemented DST were included in this study. Information regarding SRIs occurring in all inpatient (hospital and observation beds), outpatient (outpatient facilities), and ambulatory care settings (ambulatory surgical, procedural, or dialysis centers) was available in aggregate for the specified time periods.

Box 1 As part of a commitment to safety, all healthcare workers in the organization are encouraged to voluntarily report any event, incident, or condition that could result or did result in patient harm (SRI)

A patient safety-related incident is any unintended event/circumstance which could/did result in harm to a patient. A patient safety incident can be, but is not necessarily the result of:

- A defective system or process design
- A system breakdown
- Equipment failure
- Human error

Issues related to the natural course of the patient's illness or underlying condition, adverse drug reactions, or known complications that may result from a procedure or treatment are not considered patient safety incidents. Adverse drug reactions are also not considered patient safety incidents.

Due to prior internal data indicating significant variation in the number of SRIs reported based on day of the week, all SRIs occurring 7 days following the transition into and out of DST were obtained. Also, previous research has shown that the effects of sleep deprivation secondary to DST persist beyond the day of the time change.[11] For comparison, all SRIs reported in the week preceding the time change were obtained. The time change immediately preceding the transition into and out of DST was chosen to mitigate the risk of significant variation in the number of encounters and staffing.

SRIs likely resulting from human error were identified separately and include the following: medication errors-wrong dose, time, concentration, route, patient, indication and administration despite known allergy or drug-to-drug interaction; surgical errors-wrong procedure, implant, site/-side, contamination and error in surgical counts; laboratory error-mislabeled specimens. SRIs that were excluded from this group included falls, assaults, self-injury, delay in results, equipment failure, spills, miscellaneous, and other environment-related events.

The changes in the number of SRIs (either all SRIs or SRIs restricted to those likely resulting from human error) from the week before and after the time change (either spring or fall) were modeled using a negative binomial mixed model with a random effect to correct for non-independent observations in consecutive weeks. For each type of error (all or restricted to human errors), we estimated the difference between fall and spring changes in error by including an interaction with season.

RESULTS

Over the 8-year period, there were more SRIs in the 7 days following DST transitions in both spring (all: 2812 V. 2699) and fall (all: 3207 V. 3007). In addition, there were more human error-related SRIs following the change in time in both spring (human error-related SRIs: 1902 V. 1625) and fall (human error-related SRIs: 2189 V. 2087) (Table 1).

Following analyses utilizing negative binomial mixed models, we observed 4.2% (95% CI: − 1.1 to 9.7%; $p = 0.12$) and 8.8% (95% CI: − 2.5 to 21.5%; $p = 0.13$) increases in overall SRIs in the 7 days following DST when compared with 7 days prior for spring and fall, respectively (see Table). By restricting to SRIs likely resulting from human errors, we observed 18.7% (95% CI: 5.6 to 33.6%; $p = 0.004$) and 4.9% (95% CI: − 1.3 to 11.5%; $p = 0.12$) increases for spring and fall, respectively. While there was no large difference between fall and spring DST error increase of SRIs in general ($p = 0.53$), the increase in human errors was higher in spring compared with fall ($p = 0.018$). Details with regard to the number of human error-related SRIs in each major category are provided in Table 2.

DISCUSSION

Following the 1-h reduction in sleep opportunity that occurs with the transition to DST in spring, there was a significant increase in human error-related SRIs which can jeopardize patient safety. As expected, there was no significant change in human error-related SRIs following the transition out of DST in fall.

Sleep loss following spring forward has previously been shown to be associated with an increased risk of motor vehicle accidents.[11] To our knowledge, the impact of partial sleep deprivation resulting from the transition into DST on SRIs has not been explored. Previous reports have indicated that one out of 10 patients could experience an in-hospital SRI; up to half of these are likely preventable.[12] These SRIs could have significant financial implications.[13] In addition, some estimates indicate that there could be up to 210,000 patient deaths per year secondary to medical errors.[14] Extrapolating from our results, at least a portion of these SRIs could result from sleep deprivation secondary to DST. Thus, overall, the

Table 1 Number of Total and Likely Human Error-Related Safety Incidents in the Weeks Preceding and Following the Spring and Fall Time Changes

	2010	2011	2012	2013	2014	2015	2016	2017	Total
All safety-related incidents									
Spring—week following DST starting	56	210	423	399	396	368	440	520	2812
Spring—week prior to DST starting	54	155	411	415	354	375	443	492	2699
Human error-related safety incidents									
Spring—week following DST starting	45	161	304	261	277	241	278	335	1902
Spring—week prior to DST starting	44	86	262	262	209	207	276	279	1625
All safety-related incidents									
Fall—week following DST ending	179	394	463	437	334	467	461	472	3207
Fall—week prior to DST ending	102	395	381	436	368	435	478	412	3007
Human error-related safety incidents									
Fall—week following DST ending	136	263	331	300	215	330	307	307	2189
Fall—week prior to DST ending	80	263	289	315	243	298	319	280	2087

DST, daylight savings time

implementation of DST each year could potentially have substantial safety-related costs.

Prior research has shown that as few as 14% of SRIs experienced by patients are captured by US hospitals. The current study relied exclusively on self-reported SRIs. In response to the Department of Health and Human Services report on incident reporting systems and as part of an overarching commitment to safety and improving quality of care, concerted efforts to enhance SRI reporting have been undertaken by the organization. There remains a possibility that a proportion of the SRIs that occurred went undetected. However, we would not expect a significant change in SRI reporting rates in 2 consecutive weeks.

As the healthcare workforce is potentially chronically sleep deprived, we could expect a reduction in SRIs after the transition out of DST. In our study, there were no significant changes in SRIs following the transition out of DST in fall. Some studies have shown that extending sleep in laboratory setting can result in improvements in speed of response but not in accuracy. In addition, this required extended sleep duration for at least a week.[15] Another study of healthy adults did not show an improvement in executive function following 6 days of extended sleep.[16] Also, there are studies reporting that the time change following the transition out of DST in fall can also result in sleep disruption.[17] Thus, the increased opportunity to sleep following the "fall backward" may not necessarily translate into increased total sleep time and if it does, that might not translate to improved cognitive performance. Finally, these transitions into and out of DST could impact patient sleep duration, vigilance, and cooperation, which in turn could also impact the rate of SRIs.

Table 2 Category of Human Error-Related Safety Incidents in the Weeks Preceding and Following the Spring and Fall Time Changes

	Category of human error			
	Medication	Lab	Procedural	Total
Spring—week following DST starting	1236	438	228	1902
Spring—week prior to DST starting	1040	373	212	1625
Fall—week following DST ending	1469	458	262	2189
Fall—week prior to DST ending	1378	438	271	2087

DST, daylight savings time

The American Academy of Sleep Medicine in its public health advisory on mitigation of the effects of the spring forward recommends trying to obtain at least 7 h of sleep on the night prior to transition, attempting a graduated adjustment of sleep-wake time starting 2–3 days prior to the transition, and exercising caution while performing tasks that require maximal alertness.[18] Additional measures from healthcare organizations to reduce the risk of errors could include implementation of a later start time for a few days following the spring forward in order to allow employees to obtain adequate sleep.

Our study should be considered in light of some limitations. First, there would be fewer hours in the day following transition into DST as compared with the day after transition out of DST. Even if this did contribute to the difference in the number of voluntarily reported safety-related incidents, we would expect the effect of a 2-h difference to be miniscule. Second, while we had access to the total number of safety-related incidents, information with regard to the total number of encounters/opportunities of provider-patient interaction (that would allow for a calculation of rates) was not available. However, we would not expect a substantial change in the volumes of these interactions across 2 consecutive weeks. Additionally, we examined the changes in the number of safety-related incidents following transition out of DST in fall to serve as a comparator. Third, information regarding the type of healthcare worker reporting the SRI, their shift-worker status, and level of patient contact was not available. Finally, these results are from a single healthcare organization with sites located in multiple states and should be considered preliminary. Future prospective studies that systematically examine SRIs occurring following transition into and out of DST involving multiple organizations identified using voluntary reports, trigger tools, and advanced analytics are required, both to confirm these findings and to better delineate which particular SRIs, and under what

circumstances, are most likely to increase following this spring forward.

In conclusion, our data indicate an increase in human error-related SRIs following the spring forward transition into DST. Larger prospective studies are required to confirm these findings. In the interim, policy makers and healthcare organizations should evaluate delayed start of shifts or other contingency measures to mitigate the increased risk of SRIs during this period.

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Compliance with Ethical Standards:

Conflict of Interest: *The authors declare that they do not have a conflict of interest.*

REFERENCES

1. **Lo JC**, **Groeger JA**, **Santhi N**, **Arbon EL**, **Lazar AS**, **Hasan S**, et al. Effects of partial and acute total sleep deprivation on performance across cognitive domains, individuals and circadian phase. PloS one. 2012;7(9):e45987. doi:https://doi.org/10.1371/journal.pone.0045987
2. **Pilcher JJ**, **Huffcutt AI**. Effects of sleep deprivation on performance: a meta-analysis. Sleep. 1996;19(4):318-26. doi:https://doi.org/10.1093/sleep/19.4.318
3. **Killgore WDS**. Effects of sleep deprivation on cognition. Prog Brain Res. 2010;185:105-29. doi:https://doi.org/10.1016/B978-0-444-53702-7.00007-5
4. **Wertz AT**, **Ronda JM**, **Czeisler CA**, **Wright KP, Jr.** Effects of sleep inertia on cognition. JAMA. 2006;295(2):163-4. doi:https://doi.org/10.1001/jama.295.2.163
5. **Landrigan CP**, **Parry GJ**, **Bones CB**, **Hackbarth AD**, **Goldmann DA**, **Sharek PJ**. Temporal Trends in Rates of Patient Harm Resulting from Medical Care. New England Journal of Medicine. 2010;363(22):2124-34. doi:https://doi.org/10.1056/NEJMsa1004404
6. **Barger LK**, **Ayas NT**, **Cade BE**, **Cronin JW**, **Rosner B**, **Speizer FE**, et al. Impact of extended-duration shifts on medical errors, adverse events, and attentional failures. PLoS Med. 2006;3(12):e487-e. doi:https://doi.org/10.1371/journal.pmed.0030487
7. **Taffinder NJ**, **McManus IC**, **Gul Y**, **Russell RC**, **Darzi A**. Effect of sleep deprivation on surgeons' dexterity on laparoscopy simulator. Lancet. 1998;352(9135):1191 doi:https://doi.org/10.1016/s0140-6736(98)00034-8
8. **Mansukhani MP**, **Kolla BP**, **Surani S**, **Varon J**, **Ramar K**. Sleep deprivation in resident physicians, work hour limitations, and related outcomes: a systematic review of the literature. Postgraduate medicine. 2012;124(4):241-9. doi:https://doi.org/10.3810/pgm.2012.07.2583
9. **Lahti TA**, **Leppamaki S**, **Lonnqvist J**, **Partonen T**. Transition to daylight saving time reduces sleep duration plus sleep efficiency of the deprived sleep. Neuroscience letters. 2006;406(3):174-7. doi:https://doi.org/10.1016/j.neulet.2006.07.024
10. **Harrison Y.** The impact of daylight saving time on sleep and related behaviours. Sleep Medicine Reviews. 2013;17(4):285-92. https://doi.org/10.1016/j.smrv.2012.10.001
11. **Coren S.** Daylight Savings Time and Traffic Accidents. New England Journal of Medicine. 1996;334(14):924-5. doi:https://doi.org/10.1056/nejm199604043341416
12. **de Vries EN**, **Ramrattan MA**, **Smorenburg SM**, **Gouma DJ**, **Boermeester MA**. The incidence and nature of in-hospital adverse events: a systematic review. Quality & safety in health care. 2008;17(3):216-23. doi:https://doi.org/10.1136/qshc.2007.023622
13. **Slawomirski L**, **Auraaen A**, Klazinga NS. The economics of patient safety. 2017. https://doi.org/10.1787/5a9858cd-en
14. **James JT**. A new, evidence-based estimate of patient harms associated with hospital care. J Patient Saf. 2013;9(3):122-8. doi:https://doi.org/10.1097/PTS.0b013e3182948a69
15. **Dewald-Kaufmann JF**, **Oort FJ**, **Meijer AM**. The effects of sleep extension on sleep and cognitive performance in adolescents with chronic sleep reduction: An experimental study. Sleep Medicine. 2013;14(6):510-7. https://doi.org/10.1016/j.sleep.2013.01.012
16. **Rabat A**, **Arnal PJ**, **Monnard H**, **Erblang M**, **Van Beers P**, **Bougard C**, et al. Limited Benefit of Sleep Extension on Cognitive Deficits During Total Sleep Deprivation: Illustration With Two Executive Processes. Frontiers in Neuroscience. 2019;13(591). doi:https://doi.org/10.3389/fnins.2019.00591
17. **Borisenkov MF**, **Tserne TA**, **Panev AS**, **Kuznetsova ES**, **Petrova NB**, **Timonin VD**, et al. Seven-year survey of sleep timing in Russian children and adolescents: chronic 1-h forward transition of social clock is associated with increased social jetlag and winter pattern of mood seasonality. Biological Rhythm Research. 2017;48(1):3-12. doi:https://doi.org/10.1080/09291016.2016.1223778
18. https://aasm.org/daylight-saving-time-advice/. Accessed 14th March 2020 2020.