A seasonal pattern of hospital medication errors in Alaska

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Abstract

Specific behavioral consequences of seasonal affective disorder have not been closely examined. Length of daylight is evaluated in relation to medication errors in a medical center located in the far north. Factors such as numbers of patient admissions, discharges, and deaths were controlled with data collected in Anchorage, Alaska, over 5 consecutive years, 1985–89. These data revealed that 58% of all medication errors occurred during the first quarter of the year. Medication errors were 1.95 times more likely in December than September. The best statistical prediction was for errors associated with levels of darkness 2 months earlier. There may be not only an impairment of work performance among hospital nursing staff that reaches a peak in late winter but, more importantly, medication errors appear to follow a pattern that is closely associated with the annual cycle of daylight and darkness.

Keywords: Seasonal affective disorder; Seasonal depression; Circannual rhythms; Work performance

1. Introduction

The influence of seasonal variation in daylight and darkness on mood has been extensively documented. The symptoms of seasonal affective disorder (SAD) include recurrent fall-winter sleep difficulties, depressed mood, loss of energy, and difficulty concentrating (Parker and Walter, 1982; Rosenthal et al., 1984; Wehr et al., 1987; Thompson and Isaacs, 1988). SAD has been described as "recurrent depressive episodes that occur annually at the same time each year" (Rosenthal et al., 1984). The vast majority of those who suffer from seasonal depressive episodes become depressed in the fall or winter and recover in the spring. Researchers have identified SAD in 4.3% and subsyndromal SAD (fewer and/or less severe symptoms) in 14.6% of the population of New York City (Terman et al., 1988). Others found 9.2% SAD and 19% subsyndromal SAD in Alaska (Booker and Hellekson, 1992). Among both community members and clinical populations, SAD is more common in women than men, at a ratio of as much as 4:1 (Hellekson, 1989).

While this disorder is defined by both depressed mood and malaise, specific behavioral consequences such as the impairment of work performance have not yet been closely examined. Among industrial workers in northern Norway, however,
there was evidence of an increase in multiple work-related accidents associated with other mid-winter symptomatology (Jacobsen et al., 1987). Elsewhere it has been reported that 23% of the population in northern Norway suffers from mid-winter insomnia, accompanied by daytime fatigue and diminished work capacity (Lingjaerde et al., 1986). The performance of health professionals, particularly in northern environments, may be adversely affected by seasonal changes.

Previous evidence suggests that seasonal depressive episodes may not necessarily coincide with the month of least available daylight. Among SAD patients in New York state, depressive symptoms were found to peak during January and February (Terman et al., 1988). Others have demonstrated that “winter depressions usually begin in November and end in March,” with sleep disturbances, for example, most prevalent in January and February (Wehr and Rosenthal, 1989). Similarly, one of the authors (J.M.B., unpublished finding) found that SAD symptoms (e.g., depressed mood and sleep problems) were most prevalent in January and February among residents of Fairbanks, Alaska (see Booker and Hellekson, 1992). The effects of winter darkness appear to extend beyond the winter solstice in December.

Hospital medication errors have not been studied previously in relation to seasonality. The medical, pharmaceutical, and nursing literature offers an abundance of articles on drug errors. However, the primary focus in this literature is the recognition of medication errors, the training of staff in the prevention of medication errors, and the manner of classifying these errors (McNeilly, 1984; Betz and Levy, 1985; Cohen, 1989). Significant associations were found between medication errors and work-load factors on an adult intensive care unit, with errors associated with the number of patient admissions, discharges, and deaths on the day shift (Girotti et al., 1987). Medication errors also tended to increase with double patient assignments and were more common on the day shift than on the night shift.

Other studies have attempted to evaluate the relation between shift length and nurses’ performance. Researchers found that patient care tends to suffer in the last hours of both 8- and 12-h shifts compared with earlier hours in each shift (Vik and MacKay, 1982). Others found no significant relationship between the 12-h work shift, compared with shifts of shorter lengths, and nurses’ medication errors (Jones and Brown, 1986). Nursing proficiency may be more affected when nurses are not allowed to choose the shift length they prefer (Niemier and Healy, 1984). Accidents, including medication errors, among nurses were shown to be related to rotating shift work and the underlying disruption of the sleep/wake cycle (Gold et al., 1993). Work site and environmental factors are recognized as affecting the performance of nurses, but the nature of the relationship remains unclear.

This study examines the relationship between hospital medication errors and seasonality in a far north work environment. Common work factors, potentially implicated in medication errors, are controlled so that the relation between seasonal patterns of daylight/darkness and the occurrence of errors can be evaluated.

2. Methods

Anchorage, Alaska, lies at 61° north latitude, a geographic location with extremes of daylight and darkness. The Anchorage summer solstice, on June 21, brings 19 h and 28 min of available daylight, while at winter solstice, December 21, there are 18 h and 37 min of darkness. The seasonal extremes at high latitude, including darkness, cold and snow, challenge Alaskan residents in many ways.

2.1. Medication errors

Recorded medication error data from October 1, 1984, through September 30, 1989, were gathered at a 140-bed, acute care medical center located in Anchorage, Alaska. The daily inpatient census ranged between 90 and 110 patients. The nursing service, responsible for the administration of all medications, was composed of 20 supervisory clinical nurses, including nurse managers, assistant nurse managers, and house supervisors for three medical-surgical units; three specialty units (pediatrics, obstetrics, and intensive care); a four-suite operating room; and a recovery room. The patient care nursing staff included 127 employees, composed of registered nurses, licensed
practical nurses, and nursing assistants. Staff backup is provided by a pool of registered nurses, available on an intermittent, as-needed basis, and through voluntary overtime by regular staff members.

Medication errors were defined as (1) an omission of a scheduled medication; (2) medication given at the wrong time (30 min before or after the prescribed time); (3) medication given to the wrong patient, (4) in the wrong dose, or (5) the wrong medication; (6) an error in transcription of the physician's order to the medication administration record; (7) medication given to a patient with a known allergy to the drug; (8) a medication repeated without a physician's order; (9) a medication given by the wrong route of administration; or (10) a medication discontinued without an authorized physician's order.

The information on nurses' medication errors was obtained from nursing quality assurance data. This data collection process had been in place since 1982 and followed the hospital fiscal calendar, October 1–September 30 of each year. The errors reported in this study were documented on the standard error reporting form by the nurse committing the error and/or by the staff member discovering the error. The initial data on medication errors were reviewed by the nursing quality assurance coordinator, and a second review was done by the nursing quality assurance assistant.

2.2. Confounding factors

Previous studies point to a variety of working conditions as potential explanations for medication errors. Both work load, indicated by admissions, discharges, deaths, etc., and shift work have been shown to be associated with the occurrence of errors.

At this facility, standard nursing shifts are 12 h long. The usual work pattern is three consecutive 12-h shifts, followed by 2 days off, then three consecutive 12-h shifts plus one 8-h shift, and 5 consecutive days off. This schedule totaled 80 work hours every 2 weeks. The majority of nursing staff do not work rotating shifts, and overtime is voluntary. Shift length and dayshift-nightshift differences were not, therefore, examined in this study.

It was necessary to control statistically for work-load influences to examine the relation between seasonal variation in darkness and nurses' medication errors, since the work-load variables themselves may be seasonally patterned. Nine potential confounding factors were identified in the available hospital records. These include the following: vacancies — % total nursing positions vacant each month; new nurses — % new nurses among the total staff; overtime — total overtime shifts (12 h) by regular nursing staff; temporaries — total shifts (12 h) by temporary/intermittent nurses; leave — total hours of unscheduled leave for regular nursing staff; admissions — total patient admissions; discharges — total patient discharges; deaths — total patient deaths; patient days — total number of inpatient days.

2.3. Darkness

Daylight and darkness tables prepared by the U.S. Weather Bureau in Anchorage, Alaska, were used to estimate the average hours of darkness each month throughout the year. Monthly averages ranged from 18.6 h of darkness in December to only 4.5 h in June, with an annual average of 11.7 h of darkness.

2.4 Statistical considerations

To facilitate the comparison of medication error rates, the data are grouped by month over the 5-year period of the study. These grouped data provide monthly totals or averages for the variables of interest, and allow the examination of the ecological relationship between errors and average darkness per month.

Medication errors, and several of the controls, are counts of events (e.g., number of nursing vacancies) and may not be normally distributed. The skewness of these data often presents problems for the application of statistical models such as regression (Kleinbaum et al., 1988). Poisson regression, reflecting the underlying nature of the data, was used for the multivariate analysis.

3. Results

Table 1 shows 5 years of data, 1985–89, on nurses' medication errors. The distributions for each year and month are presented, along with the cumulative distribution for the 5 years of the study. There is considerable variation in overall
medication errors from one year to the next, but all years show an increase in errors during the late fall and winter months. Over the course of the 5 years, the largest percentage of errors occurred in the late winter, March (29%) and February (22%), with 58% of all nurses' medication errors being reported during the first quarter of the year. Log-linear analysis of the observed medication errors per month, over 5 years, provided a comparison with the expected (equi-probability) occurrence of errors. The results indicate that the observed (seasonal) pattern of medication errors is not likely random variation in the data ($\chi^2 = 184.76, df = 11, P < 0.001$).

Table 2 presents the means, standard deviations, and modes for all variables. Nurses' medication errors averaged 4.45 each month over the 5 years of the study. Vacant nursing positions averaged 4.25 per month, with about three new registered nurses joining the staff each month. Overtime among regular nursing staff averaged more than 68 shifts (816 h) per month, temporary nursing staff contributed almost 87 shifts (more than 1000 h) per month, and over 4000 h (373.67 shifts) of unscheduled leave were claimed each month. Admissions, discharges, and deaths were fairly stable over the period of the study, indicated by the relatively small standard deviations for these variables.

Table 3 presents the results of the initial Poisson regression of errors on darkness and the workload measures. The results reflect a simultaneous solution where the unique effect of each variable is estimated while controlling for all other variables in the equation. Interaction terms were not included in the analysis. The findings indicate that as admissions and overtime increase, there tends to be a decrease in medication errors, and that an increase in temporary staff and patient days is associated with an increase in errors. Other workload variables do not reach significance in these data.
Table 4
Odds ratios for medication errors with levels of delay in darkness effect

<table>
<thead>
<tr>
<th>Model</th>
<th>Odds ratio</th>
<th>95% confidence interval</th>
<th>P ≤</th>
<th>LR</th>
<th>LRb</th>
</tr>
</thead>
<tbody>
<tr>
<td>No delay</td>
<td>1.02</td>
<td>1.01-1.05</td>
<td>0.1450</td>
<td>114.2</td>
<td></td>
</tr>
<tr>
<td>+1 month</td>
<td>1.07</td>
<td>1.04-1.09</td>
<td>0.0000</td>
<td>130.6</td>
<td></td>
</tr>
<tr>
<td>+2 months</td>
<td>1.11</td>
<td>1.08-1.15</td>
<td>0.0000</td>
<td>156.0</td>
<td></td>
</tr>
<tr>
<td>+3 months</td>
<td>1.11</td>
<td>1.07-1.15</td>
<td>0.0000</td>
<td>155.2</td>
<td></td>
</tr>
</tbody>
</table>

*Probability for darkness coefficient; bLikelihood ratio statistic for overall model (df = 3).

Darkness also does not reach significance in this analysis. Thus, the number of medication errors in a given month may not be directly related to the number of hours of daylight or darkness during that particular month. While there appears to be a seasonal pattern to medication errors, the average number of hours of darkness per month does not provide a good prediction of how many errors will occur during that month.

To investigate this question further, the analysis in Table 3 was repeated for models with an effect delay of 1, 2, and 3 months. That is, the analysis was repeated as if winter solstice, and maximum darkness, occurred in January, then in February, and then in March. Each model examines the possibility that the effect, medication errors, occurs at some interval after the stimulus, loss of daylight. Table 4 presents the results of this modeling strategy, with the coefficients for the darkness parameter converted to odds ratios and 95% confidence intervals. The probabilities shown are for the darkness parameter alone, while the likelihood statistic, which approximates the $\chi^2$ statistic, reflects the effect of the overall model (Kleinbaum et al., 1988). For the original model (no delay), an odds ratio of 1.02 is derived, indicating no significant increase in likelihood of medication errors for each 1 h of decrease in daylight. The overall model

Fig. 1. Medication errors and annual daylight/darkness cycles, actual vs. delayed, 1985–89.
is significant ($\chi^2 > 9.84, df = 3, P < 0.01$), reflecting the effect of the work-load variables included in the analysis.

With a 1-month delay between loss of daylight and the occurrence of medication errors, however, the odds ratio for errors becomes significant, increasing to 1.07 for each added hour of darkness. With a 2-month delay, the odds ratio again increases, to 1.11. A 3-month delay (to March) produces the same odds ratio, but with decreasing precision, shown in the slightly wider confidence interval. The model likelihood ratio also increases significantly with a 1- and 2-month delay, but it begins to decline at 3 months. These findings suggest that the best fit may be a model that would predict medication errors based on the level of darkness 2 months earlier in the year. Fig. 1 illustrates this model, comparing the cycle of darkness to medication errors, with no delay and with a 2-month delay. It is evident that the delayed effect model more closely matches the actual seasonal pattern of errors.

In the model based on a 2-month delay in effect of darkness, three work-load factors remain significant. Errors remain positively associated with the number of shifts worked by temporary staff (odds ratio = 1.01, $P = 0.0000$) and negatively associated with overtime shifts (odds ratio = 0.98, $P = 0.003$) and patient days (odds ratio = 1.61, $P < 0.0000$). While increased overtime may result in impaired performance due to fatigue, it may also mean that those working overtime represent the more experienced nurses on staff. Increased use of temporary nursing staff and a heavier patient load might be expected to lead to more medication errors. Hospital admissions are no longer associated with medication errors, likely the result of controlling for a seasonal pattern in admissions themselves.

While the observed odds ratio for darkness appears relatively small, it must be remembered that the value shown corresponds to the increased likelihood of medication errors for each additional hour of darkness. Therefore, the difference in daylight between equinox (September 21) and winter solstice (December 21), a loss of 6.3 h, would mean that medication errors are 1.95 times (ln odds ratio = $6.3 \times 0.106$) more likely in February than November. Medication errors appear to be significantly, and substantially, associated with the seasonal pattern of darkness.

4. Discussion

Data collected in Anchorage, Alaska, over 5 consecutive years, 1985–89, show a pattern of nurses' medication errors associated with the seasonal pattern of daylight and darkness. The 5-year data revealed that 58% of all nurses' medication errors occurred during the first quarter of the year, January–March.

After controls were applied for a number of work-load factors — several of which proved to be associated with medication errors — monthly average darkness levels were positively related to errors. The relationship was not evident within any single month, however, but emerged between the length of darkness in a given month and the rate of errors in a subsequent month. The best statistical prediction was found for errors associated with levels of darkness 2 months before the month under observation. For example, the amount of daylight available in Anchorage in December was best correlated with the number of errors that occurred in February.

The crucial issue for these findings is their biological plausibility, given what is understood about the effects of seasonal changes in daylight. Phototherapy trials have generally shown that SAD symptoms subside within a week of the initiation of therapy and that those symptoms may return in about an equal time when the treatments are stopped (Terman et al., 1989). Depressive episodes have also been shown to last well into the late winter months (Wehr and Rosenthal, 1989). Depressed mood and sleep disturbances, in particular, seem to reach a peak in January and February (Terman et al., 1988). Our results indicate not only that there may be seasonal impairment of work performance among hospital nursing staff, but that the pattern of medication errors is most closely related to levels of daylight exposure that may have existed 2 months earlier.

These results may prove useful in drawing attention to problems associated with the performance of complex work tasks during winter months, such
as medication administration, which have a high risk of error. Seasonal depression is a widespread phenomenon most prevalent among populations in the far north. Based on the estimated prevalence for SAD and subsyndromal SAD in Alaska (Booker and Hellekson, 1992), as many as one of four members of the nursing staff may experience an increased risk for medication errors in association with winter darkness. In addition, large numbers of people have been shown to be adversely affected at much lower latitudes (Rosen et al., 1990). It is important to identify behavioral and functional indicators of seasonal impairment that extend the existing model of SAD into other aspects of daily life. Furthermore, since only a relatively small proportion of the nursing staff may be adversely affected, screening and workplace interventions could be highly effective in reducing the seasonal risk of increased medication errors.

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References


