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The influence of seasonal variation on cardiac surgery: A time-related clinical outcome predictor

Jeffrey H. Shuhaiber, MD,[a] Kimberley Goldsmith, MA,[b] and Samer A. M. Nashef, FRCS[a]

Objective: The effect of seasonal variation on cardiac surgery outcomes is unknown. We investigated the effect of season on risk-adjusted hospital mortality and length of stay.

Methods: Prospectively collected data from cardiac operations at one center between April 1996 and March 2006 were analyzed. Seasonal variation in outcomes was studied by using multiple regression models that included EuroSCORE and year of operation to adjust for risk profile and changes over time. Analysis was performed for 2 separate surgical groups: patients having coronary artery bypass grafting only and patients having other cardiac procedures with or without coronary artery bypass grafting.

Results: There were 16,290 patients who had a first record of cardiac surgery in the study period between April 1, 1996, and March 31, 2006, with 10,263 patients having coronary artery bypass grafting only and 6027 patients having another procedure with or without coronary artery bypass grafting. There were increased odds of hospital mortality in patients having operations in winter compared with the average across all seasons for both surgical groups, although this was only significant in the coronary artery bypass grafting–only group (odds ratio, 1.29; 95% confidence interval, 1.01–1.63; $P =$ .04). There were decreased odds of death in the coronary artery bypass grafting–only group in summer (odds ratio, 0.76; 95% confidence interval, 0.60–0.96; $P = .02$). Intensive care unit stay was 4% (95% confidence interval, 1%–6%) longer in the coronary artery bypass grafting–only group in winter and 3% (95% confidence interval, 1%–5%) shorter in summer than the average stay ($P = .003$ and .006, respectively). There were no differences in intensive care unit stay in the combined surgery group by season and no differences in total length of stay for either group (coronary artery bypass grafting only and coronary artery bypass grafting with other cardiac procedures).

Conclusions: Cardiac surgery outcomes are influenced by the time of year. Hospital mortality and intensive care unit stay after coronary artery bypass grafting were increased during the winter season compared with the rest of the year.

From the Papworth Hospital NHS Trust, Cambridge University Teaching Hospital,[a] and *MRC Biostatistics Unit, Institute of Public Health,[b] Cambridge, United Kingdom.

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Address for reprints: Jeffrey H. Shuhaiber, MD, 6 Grassmount, Taymount Rise, London SE 23 3UW, United Kingdom (E-mail: Jeffrey01@mac.com).

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An association between seasons and coronary artery syndromes is well known.[1,2] It has been reported that the mortality rates from stroke and coronary heart disease increase during winter[3] and that coronary events are up to 40% more likely to occur in winter and spring than at other times of the year.[4] Several possible biologic and environmental explanations for this seasonal effect have been postulated, such as change in ambient temperature.[4] There is information on seasonal variation after acute coronary syndromes in the cardiology literature[5-7] but virtually no data on any effects of seasonal variation on cardiac surgery outcomes. The EuroSCORE adjusts for several physiologic, cardiovascular disease–related, and operation–related factors. We used this score. The purpose of the present study is to assess the effect of season on cardiac surgery outcomes.

Materials and Methods

We analyzed routinely collected hospital episode data on all cardiac surgery patients undergoing operations at Papworth Hospital between April 1996 and March 2006. Seasons were coded

Abbreviations and Acronyms

CABG = coronary artery bypass grafting
CI = confidence interval
ICU = intensive care unit

as follows: autumn (September 21 through December 20), winter (December 21 through March 21), spring (March 22 through June 21), and summer (June 22 through September 20). Continuous variables were reported as means and standard deviations or medians and interquartile ranges, whereas categorical variables were reported as frequencies and proportions within season of operation. The relationship between season of operation and patient characteristics (unadjusted) was examined by using analysis of variance, Kruskal–Wallis tests, or Pearson χ^2 tests, as appropriate.

Analysis was performed separately for 2 surgical groups as follows: one group with patients having coronary artery bypass grafting (CABG) only and the other with patients having another cardiac procedure with or without CABG. Outcome measures were in-hospital mortality, length of stay in the intensive care unit (ICU), and hospital stay.

Seasonal variation in hospital mortality was studied by using multiple logistic regression models that included EuroSCORE and year of operation to adjust for risk profile and changes over time. The EuroSCORE adjusts for several physiologic, cardiovascular disease–related, and operation–related factors that include a total of 17 potentially confounding variables. Separate models were run for the 2 surgical groups. Each season was compared with the overall mean if global tests for the season variable were significant at a P value of .1 or less.

Seasonal variation in ICU and hospital lengths of stay was examined by using general linear models. The natural logarithm transformation of ICU stay in minutes and hospital stay in days was used because of the skewed nature of these distributions. Patients who died in the ICU were removed from the analysis of ICU stay; similarly, patients dying before discharge from the hospital were excluded from analysis of hospital stay. As in the case of hospital mortality, EuroSCORE and year of operation were included in the models, separate models were run for the 2 surgical groups, and each season was compared with the overall mean if global tests for the season variable were significant at a P value of .1 or less.

Results

There were 16,290 patients who had a first record of cardiac surgery between April, 1, 1996, and March 31, 2006, with 10,263 patients having CABG only and 6027 patients having had another procedure with or without CABG. Table 1 shows a breakdown of these latter operations by type.

We found there were no significant differences in observed and expected deaths, as predicted by the EuroSCORE, either in the whole study group or in the CABG and CABG/other groups separately ($P = .69$, .55, and .52, respectively).

Within each surgical group, patients were broadly similar across the seasons, with the following exceptions: patients having CABG operations in winter were older and more were hypertensive ($P \leq .04$). Patients having CABG operations in autumn were more likely to have had a previous myocardial infarct ($p = .01$). Chronic pulmonary disease was more common in patients having operations in autumn, and unstable angina was more common in patients having operations in summer in both groups (both $P < .001$, Table 2).

TABLE 1. Type and number of operations in combined and other cardiac operations in cardiac surgical patients between April 1, 1996, and March 31, 2006

Type of operation	No. (%)
CABG plus operation of the thoracic aorta	61 (1.0)
CABG plus valve(s) procedure	1717 (28.5)
CABG plus thoracic aorta and valve(s) procedure	62 (1.0)
CABG plus other operation	498 (8.3)
Operation of the thoracic aorta	218 (3.6)
Valve(s) procedure	3040 (50.4)
Operation of the thoracic aorta and valve(s) procedure	267 (4.4)
Other operation	164 (2.7)
Total	6027

CABG, Coronary artery bypass grafting.

There were no significant seasonal differences in unadjusted ICU mortality, hospital mortality, or length of hospital stay in either surgical group (Tables 2 and 3). There was a significant difference in ICU stay across seasons in the CABG group ($P = .001$ for the CABG and $P = .07$ for combined CABG/other groups).

There was borderline significant seasonal variation in the odds of hospital mortality adjusted for EuroSCORE and surgical year in the CABG group (overall $P = .06$, Figure 1). Patients undergoing CABG had 1.29 times the odds (95% confidence interval [CI], 1.01–1.63) of dying in the hospital in winter compared with the average across all seasons ($P = .04$). There were decreased odds of death in the CABG-only group in summer; patients having operations in summer had a reduction in their odds of death of 24% (95% CI, 4%–40%; $P = .02$). Patients in the combined/other group were also more likely to die in the hospital in winter, but this finding did not reach significance (odds ratio, 1.17; 95% CI, 0.95–1.43).

ICU stay was 4% (95% CI, 1%–6%] longer in the CABG-only group in winter and 3% (95% CI, 1%–5%) shorter in summer than the average stay ($P = .003$ and .006, respectively; Figure 2). There were no differences in ICU stay in the combined group by season and no evidence of seasonal variation in hospital length of stay in either group (data not shown for the latter).

Discussion

Seasonal variation of clinical diagnoses was noted as long ago as the turn of the century. Certain diseases tend to occur

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TABLE 2. Characteristics by season of operation in patients undergoing CABG-only procedures

Characteristic	Spring (n = 2569)	Summer (n = 2651)	Autumn (n = 2601)	Winter (n = 2442)	*P* value
Mean age (SD)	65.6 (9.22)	65.4 (9.31)	65.4 (9.53)	66.1 (9.15)	.03
Male sex (%)	2070 (80.6)	2128 (80.3)	2084 (80.1)	1974 (80.8)	.93
Mean EuroSCORE (SD)	3.7 (2.76)	3.8 (2.93)	3.6 (2.84)	3.7 (2.76)	.14
Mean logistic EuroSCORE (SD)	4.1 (5.52)	4.5 (6.72)	4.2 (6.63)	4.2 (6.12)	.10
Median ICU stay, d (IQR)*	0.9 (0.22)	0.9 (0.21)	0.9 (0.21)	0.9 (0.24)	.001
Median hospital stay, d (IQR)†	7.1 (3.12)	7.0 (3.13)	7.0 (2.97)	7.1 (3.06)	.27
Unadjusted ICU mortality (%)	22 (0.9)	17 (0.6)	18 (0.7)	15 (0.6)	.72
Unadjusted hospital mortality (%)	63 (2.5)	56 (2.1)	66 (2.6)	63 (2.6)	.65
Comorbidities (%)					
Hypertension	1460 (56.8)	1461 (55.1)	1497 (57.6)	1442 (59.0)	.04
Renal failure	19 (0.7)	24 (0.9)	18 (0.7)	12 (0.5)	.37
Previous MI					.01
<6 mo	411 (16.0)	385 (14.5)	467 (18.0)	415 (17.0)	
>6 mo	852 (33.2)	897 (33.8)	903 (34.7)	811 (33.2)	
Chronic lung disease	84 (3.3)	94 (3.5)	184 (7.1)	91 (3.7)	<.001
Unstable angina	179 (7.0)	264 (10.0)	115 (4.4)	119 (4.9)	<.001

CABG, Coronary artery bypass grafting; *SD*, standard deviation; *ICU*, intensive care unit; *IQR*, interquartile range; *MI*, myocardial infarction. *In those alive when discharged from the intensive care unit. †In those alive on hospital discharge.

during particular times of the year and can have worse prognoses at that time.

Seasonal variation of clinical coronary events is well recognized in the United Kingdom. However, it is unclear whether these potentially fatal events occurred suddenly or days after the onset of symptoms or whether the subject was in the hospital or out in the community.[8] In England and Wales, the winter peak in coronary and cerebrovascular disease accounts for an additional 20,000 deaths per annum.[9] Excess winter deaths remain a well-observed phenomenon, despite lack of consensus for the underlying mechanism of disease.

Little research exists with respect to seasonal variation in the field of surgery. Several risk factors related to seasonal variation have been investigated and include environmental factors (temperature and ultraviolet radiation), lifestyle factors (diet, obesity, exercise, and smoking), and other risk factors (blood pressure, serum cholesterol, glucose tolerance

TABLE 3. Characteristics by season of operation in patients undergoing combined CABG procedures and other patients

Characteristic	Spring (n = 1483)	Summer (n = 1516)	Autumn (n = 1602)	Winter (n = 1426)	*P* value
Mean age (SD)	66.4 (12.38)	67.4 (12.15)	66.6 (12.77)	66.5 (12.65)	.10
Male sex (%)	924 (62.3)	961 (63.4)	1037 (64.7)	885 (62.1)	.40
Mean EuroSCORE (SD)	6.4 (3.21)	6.5 (3.29)	6.5 (3.31)	6.5 (3.23)	.79
Mean logistic EuroSCORE (SD)	9.8 (11.52)	10.1 (11.65)	10.4 (12.24)	9.9 (11.94)	.43
Median ICU stay, d (IQR)*	0.9 (0.31)	0.9 (0.37)	0.9 (0.38)	0.9 (0.61)	.07
Median hospital stay, d (IQR)†	9.0 (6.04)	9.0 (5.96)	9.0 (5.77)	9.0 (6.01)	.84
Unadjusted ICU mortality (%)	20 (1.4)	32 (2.1)	29 (1.8)	26 (1.9)	.49
Unadjusted hospital mortality (%)	76 (5.2)	96 (6.3)	93 (5.8)	90 (6.4)	.47
Comorbidities (%)					
Hypertension	654 (44.1)	697 (46.0)	699 (43.6)	665 (46.6)	.28
Renal failure	16 (1.1)	19 (1.3)	15 (0.9)	13 (0.9)	.78
Previous MI					.61
≤6 mo	79 (5.3)	87 (5.7)	99 (6.2)	78 (5.5)	
>6 mo	152 (10.2)	181 (11.9)	192 (12.0)	166 (11.6)	
Chronic lung disease	79 (5.3)	64 (4.2)	148 (9.2)	63 (4.4)	<.001
Unstable angina	70 (4.7)	86 (5.7)	16 (1.0)	15 (1.1)	<.001

CABG, Coronary artery bypass grafting; *SD*, standard deviation; *ICU*, intensive care unit; *IQR*, interquartile range; *MI*, myocardial infarction. *In those alive when discharged from the intensive care unit. †In those alive on hospital discharge.

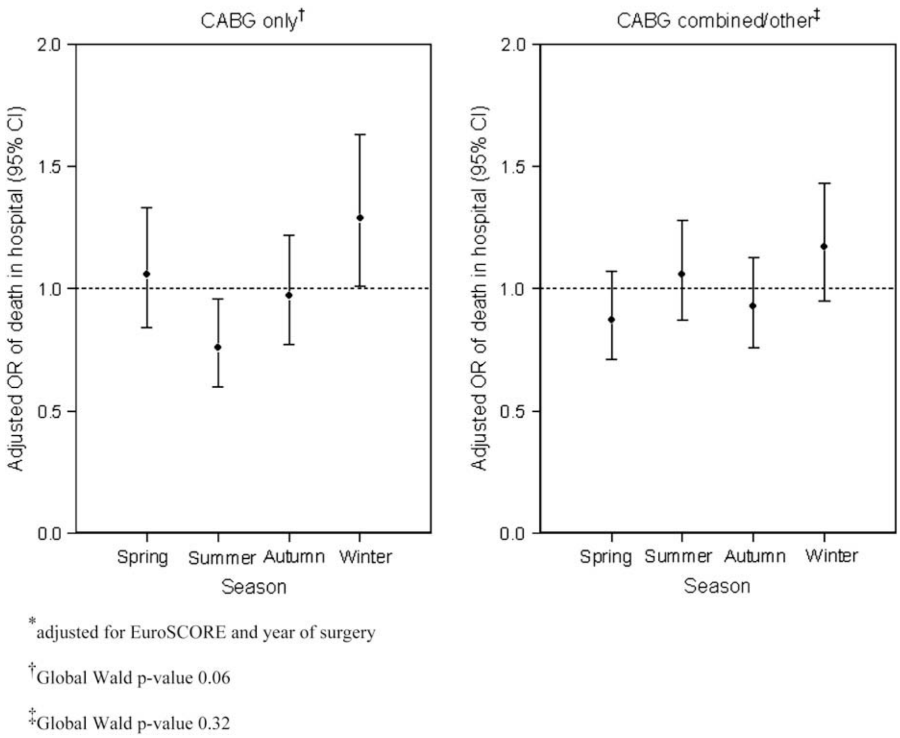

Figure 1. Adjusted* odds ratio *(OR)* of hospital mortality by season compared with the overall mean. *Adjusted for EuroSCORE and year of operation. †Global Wald, $P = .06$. ‡Global Wald, $P = .32$. *CABG*, Coronary artery bypass grafting; *CI*, confidence interval.

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and coagulation, and acute and chronic infections).[6,8] The majority of these variables attain higher prevalence during the winter season. This multifactorial disease process is now thought to be responsible for the winter peak in coronary events.

In this study risk-adjusted outcomes of CABG were worse during the winter season and better during the summer season. The risk-adjusted outcome of other and combined procedures (eg, valve plus CABG) also tended to be worse in winter. This suggests that there might be a role for seasonal variation in cardiac surgical outcomes similar to that seen in acute coronary syndromes. One important and established finding relates to the activation of the neuroaxial system in a cold climate, accelerating the atherosclerotic process and plaque instability through a cascade of hormones, cytokines, and inflammatory pathways. This has been studied in animal models. Scherlag and colleagues[10] studied the incidence of sudden death in 184 dogs after ligation of the left anterior descending coronary artery. Forty-six sudden deaths from ventricular tachyarrhythmias 13 to 22 hours after coronary artery ligation occurred between November and February (42%) compared with only 6% in July and August. Surviving dogs ($n = 138$) underwent an electrophysiologic study, during which a greater number of animals showed inducible, sustained, monomorphic ventricular tachycardia during the winter months compared with the summer months. The authors speculated that this could be due either to increased sympathetic tone or catecholamine levels.

Depression and other psychosomatic disorders, more frequent during winter, might also worsen outcomes of cardiac surgery. Seasonal affective disorder is a form of recurrent depression that appears to be precipitated by a specific stressor (winter) and resolves spontaneously in spring or summer.[11] The elements of winter that contribute to seasonal affective disorder are unknown at this time, although light deficiency is likely to play a role. During the winter, there is a decrease in both climate temperature and daylight hours. These changes are registered in the brain by the suprachiasmatic nucleus, which signals physiologic and possibly pathophysiologic processes, including cardiac arrhythmias.[12-14]

Increased mortality can also be related to increased seasonal physical and emotional stress. The findings of seasonal variation of outcome after interventional studies can be extrapolated to the field of surgery. In the Antiarrhythmics Versus Implantable Defibrillators study,[15] vital status was obtained for 4467 registered patients with sustained ventricular arrhythmias or unexplained syncope through the National Death Index as of December 31, 1996. Of these patients, 735 died, among whom 137 were discharged with an implantable defibrillator, 425 received antiarrhythmic drugs, 66 received both, and 107 received neither. In this population mortality from Thanksgiving to New Year's Day was 15%, whereas this was predicted to be 11% ($P = .002$). The pattern of increased winter holiday mortality was evident in subgroup analyses for patients in both warmer and colder parts of the United States, suggesting that the increase in mortality

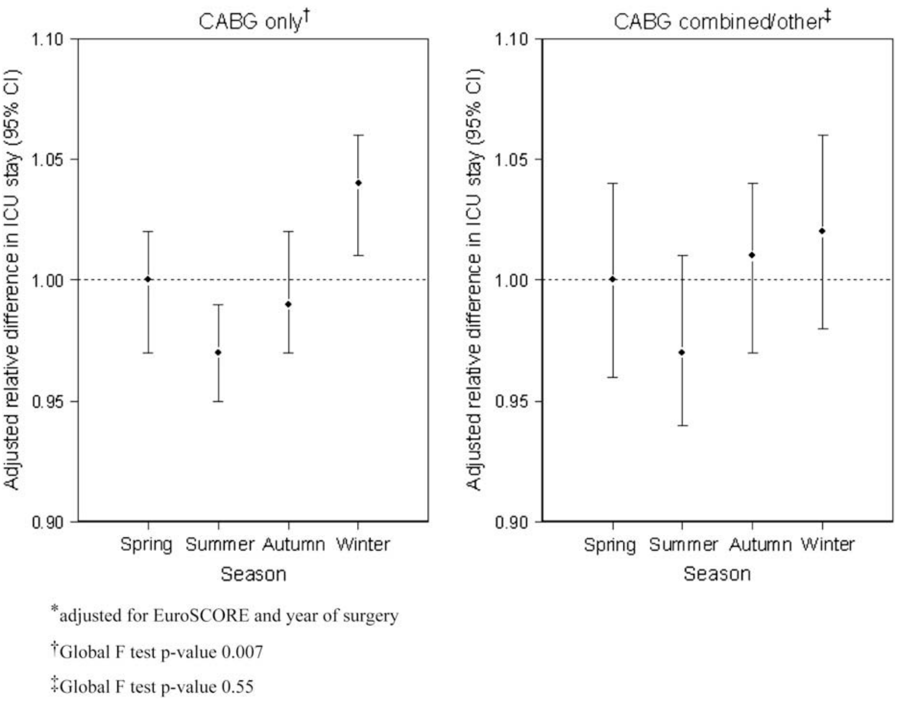

Figure 2. Adjusted* relative difference in intensive care unit *(ICU)* stay by season compared with the overall mean. *Adjusted for EuroSCORE and year of operation. †Global F test, $P = .007$, ‡Global F test, $P = .55$. *CABG*, Coronary artery bypass grafting; *CI*, confidence interval.

related to the holiday season might not be due to cold temperature alone. A study by Kloner and associates[16] analyzed 222,265 reports from the monthly death certificate data in Los Angeles County for deaths caused by coronary artery disease from 1985 through 1996. The mean number of deaths was 33% higher in December and January than in June, July, and September. These deaths could not be explained solely on the basis of the daily temperature, which is generally mild in Los Angeles at that time. The minimum daily temperature remained relatively stable, whereas the maximum temperature showed minor fluctuations during these times. The authors suggested that factors other than temperature, such as superimposed respiratory tract infections, behavioral changes around holiday time (including increased food, salt, and alcohol consumption), and emotional and psychologic stress contributed to the increase in deaths in December and the decrease after January 1.

We found a 30% increased risk of death after winter CABG operations. It is possible that the explanations already investigated for acute coronary syndromes could also apply to cardiac surgery. The stressful effect of surgical intervention could be more hazardous during winter because of the altered disease behavior seen in acute coronary syndromes. Sufficient evidence indicates that cold temperature causes pathophysiologic changes relevant to those causes of death that occur more frequently in winter. Cold exposure or cold stress might be a major factor in the increased winter incidence of deaths from cerebrovascular accident and chronic bronchitis.[17] Nonetheless, seasonal variation and cardiovascular mortality cannot be explained based on changes in temperature alone. The stress of cold is related not just to absolute temperature but also to air movement (winds or draughts) and damp altering musculoskeletal and neurosensory function. We speculate that increased CABG mortality during the winter season stems from winter-related effects superimposed on the stress of cardiac surgery.

Papworth is a dedicated heart and lung center with clear protocols for the postoperative management and discharge of cardiac surgical patients. Our study is risk adjusted and deals with well-defined patient populations, suggesting that the evidence of seasonal variation we have found is worthy of further investigation. However, to our surprise, ICU stay after CABG was longest in winter and shortest in summer. This finding was unexpected given that postoperative ICU management is run by fast-track protocols under the direct instruction of the attending intensivist in liaison with attending surgeon. A few studies have examined seasonal differences in length of stay. However, these studies' results are at conflict. Buchwald and colleagues[18] found no significant difference in length of stay in 1251 patients hospitalized during July and August with the 10 most prevalent medical and surgical diagnoses. They concluded that there was no substantial increase in the cost of care early in the training year. In contrast, a study by Rich and coworkers,[19] analyzing a larger sample of patients (n = 240,467; 25 discharge diagnoses), showed that length of stay, as well as house staff experience, increased and, perhaps surprisingly, that length of stay after surgical intervention increased over the academic year.

The clinical relevance of our findings relates to an epidemiologic observation already established in cardiovascular medicine. Given that, on average, our severity score was the same across all seasons and patients did worse than others suggests at least a seasonal influence on our pathophysiology at the time of cardiac surgery. We recommend that such an observation be shared with the consenting patient undergoing cardiac surgery during the winter season. Our findings on ICU length of stay have important considerations for funding and administration. Each time unit in the ICU has a fiscal cost. Given that most health administrations are financially challenged with the worsening global economy, difference in hours of stay can translate into thousands for one hospital and up to millions for the nation. Furthermore, these costs are only estimates of the true burden of extra stay related to factors of nursing staff and bed availability.[20]

Despite our significant findings, our study has limitations. The data are limited to a single hospital in one particular climate. We do not collect data on variables such as seasonal affective disorder, depression, and their treatment, and these were therefore not used in our risk model. Results from 2 clinical trials on patients after myocardial infarction suggest that pharmacologic treatment of depression is associated with reduced mortality and fewer cardiac events.[21,22] It is possible a β error might have confounded our results when large number of patients (typically in the thousands) permit a statistically significant conclusion. With 95% CIs, there are differences caused by chance that are found to be significant about 5% of the time, but there is a greater chance of us detecting such differences because we have a large sample size, especially when risk adjusted. It is also possible that there might be residual confounding of the relationship between mortality and length of stay and season by other administrative and logistic variables.

In summary, patients undergoing CABG have poorer outcomes in winter than in summer, and future studies should investigate the mechanisms responsible for the increased risk during the winter season. Further investigation to delineate the mechanisms and modes of therapeutic intervention, such as postponing elective operations, might reduce the winter excess of deaths.

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