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The influence of seasons and lunar cycle on hospital outcomes following ascending aortic dissection repair

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Abstract

OBJECTIVES: The effect of the lunar cycle and seasonal variation on ascending aortic dissection surgery outcomes is unknown. We investigated these temporal effects on risk-adjusted hospital mortality and then on the length of stay (LOS) following surgery for survivors.

METHODS: We examined prospectively collected data from cardiac operations at two major centres within a single state between January 1996 and December 2011. We first examined the relationship between the lunar cycle and seasonal variation, along with demographic and risk profile covariates, with mortality using univariate analyses, followed by multiple logistic regression modelling that controlled for demographic and patient risk variables including age, gender, risk profile (diabetes, hypertension, dyslipidaemia and renal failure), and two surgical groups: Group A, consisting of patients having repair of ascending aorta dissection repair only, and Group B, with those having ascending aorta repair plus aortic valve surgery or coronary bypass surgery or both. We further examined the relationship with LOS using both univariate and multiple regression analyses.

RESULTS: There were 210 patients who had repair of dissection in the study period, with 109 patients in Group A and 101 in Group B. The average age of this sample was 59.5 (standard deviation = 16.0), 65.7% were male and 18.1% died prior to discharge following repair. The greatest percentage of deaths occurred in winter (31.6%, *n* = 12), while the least were in summer (21.1%, *n* = 8) and fall (21.1%, *n* = 8). An overall χ^2 test found there was no difference in mortality for season (*P* = 0.55). Univariate analyses also found the age of patients who died vs lived was significantly higher (65.9 vs 58.1 years; *P* = 0.001), and a significantly greater (*P* = 0.029) percentage of patients with diabetes vs without diabetes died (41.7 vs 16.7%). Univariate analyses found all other covariates were not significantly related to mortality. In the multiple logistic regression model, there was no significant effect for season, while the odds of dying increased with age (odds ratio [OR] = 1.04, 95% confidence interval [95% CI] = 1.01–1.07, *P* = 0.012), and the odds of dying in the full-moon cycle vs the new moon cycle was significantly reduced (OR = 0.21, 95% CI = 0.05–0.81, *P* = 0.024). No other covariate significantly increased or decreased the odds of death, including diabetes risk, which had been significantly related to death in the univariate analysis. Within a linear regression model that examined the relationship with LOS, Group B (*P* = 0.020), male sex (*P* = 0.036) and the full-moon lunar phase (*P* = 0.001) were significantly related to shorter LOS.

CONCLUSIONS: Season had no effect on mortality or LOS following aortic dissection repair, while patient age significantly increased the odds of death. The full-moon cycle appeared to reduce the odds of death, and the full-moon cycle, along with being male and requiring a concomitant cardiac procedure, was associated with shorter LOS.

Keywords: Aortic dissection • Surgery • Outcomes • Pathophysiology risk factors • Environmental factors

INTRODUCTION

An association between seasons and cardiovascular disease is well known [1]. It has been reported that coronary events are up to 40% more likely to occur in winter and spring than at other times of the year [2, 3]. Several possible biological and environmental explanations for this seasonal effect have been postulated, such as change in ambient temperature [4, 5]. While there is information on seasonal variation after acute aortic dissection (AAD) incidence, as well as outcomes, following coronary artery bypass grafting [6–9], there is virtually no data on any effects of lunar calendar month on outcomes following AAD repair. The purpose of the present study was to assess the effect of such natural time variation of both season and lunar cycle phases on hospital survival and length of stay (LOS) following AAD repair.

METHODS

Participants and measures

We analysed routinely collected hospital episode data on all 210 cardiac surgery patients undergoing repair of aortic dissection at both the Rhode Island and Miriam Hospitals between 2 January 1996 and 18 December 2011. Seasons were coded 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). The 29-day lunar calendar month was divided into four phases of new moon, waxing moon, full-moon and waning moon. Each phase was apportioned as follows: Day 1–7 = new moon, 8–14 = waxing moon, 15–21 = -full-moon and 22–29 = waning moon.

Two surgical groups were defined as follows:

Group A had AAD repair only.
Group B had AAD plus another cardiac procedure such as valve repair.

Outcome measures were in-hospital mortality and LOS in days for survivors. In addition to the demographic variables of age and gender, additional risk profile comorbidities included as covariates were history of hypertension, diabetes, dyslipidaemia and renal failure.

Statistical analyses

Statistical analyses were performed using the IBM SPSS Statistics 20.0 software pack for Windows. Simple descriptive analyses, including the reporting of percentages, means and standard deviations, were conducted to describe the participant characteristics. Cross-sectional analyses of variables hypothesized to be related to mortality and LOS used chi-square tests for categorical variables, while *t*-tests, or analysis of variance (ANOVA) in the case of more than two grouping variables, were used to examine the relationship of continuous variables hypothesized to be related to mortality and LOS, with the Tukey *post hoc* range test used to compare individual group means with each other for a significant ANOVA. The $P < 0.05$ alpha level was used to define statistical significance for all analyses, and Welch's correction was used for a *t*-test analysis that displayed the heterogeneity of variance. Multiple logistic regression analyses were then conducted to examine the relationship of seasonal variation with hospital mortality, adjusted for surgical group, the demographic covariates of age and gender, lunar cycle categories, weekend or weekday admittance as well as the risk profile covariates of hypertension, diabetes, dyslipidaemia and renal failure. A multiple regression analysis was conducted, using the same set of covariates as was used in the multiple logistic regression, to investigate the predictors of LOS after surgery for the survivors of surgery. LOS was positively skewed and kurtotic, and a natural logarithm transformation of LOS was used to correct for non-normality for

Table 1: Comparison of mortality status by demographic and risk factors

Variable	Total (*N* = 210)	Died (*N* = 38)	Survived (*N* = 172)	*P*-value
Age[a] (SD)	59.5 (16.0)	65.9 (12.1)	58.1 (16.2)	0.001
Male (%)	138 (65.7%)	25 (65.8%)	113 (65.7%)	0.991
Female (%)	72 (34.3%)	13 (34.2%)	59 (34.3%)	
Surgical group				
Aortic repair only (%)	109 (51.9%)	18 (47.4%)	91 (52.9%)	0.536
Aortic repair plus other procedure (%)	101 (48.1%)	20 (52.6%)	81 (47.1%)	
Hypertension				
Yes (%)	148 (70.5%)	30 (78.9%)	118 (68.6%)	0.206
No (%)	62 (29.5%)	8 (21.1%)	54 (31.4%)	
Diabetes				
Yes (%)	12 (5.7%)	5 (13.2%)	7 (4.1%)	0.029
No (%)	198 (94.3%)	33 (86.8%)	165 (95.9)	
Dyslipidaemia				
Yes (%)	41 (19.5%)	9 (23.07%)	32 (18.6%)	0.475
No (%)	169 (80.5%)	29 (76.3%)	140 (81.4%)	
Renal failure				
Yes (%)	2 (1.0%)	1 (2.6%)	1 (0.6%)	0.239
No (%)	208 (99.0%)	37 (97.4%)	171 (99.4%)	
Weekend				
Yes	43 (20.5%)	6 (15.8%)	37 (21.5%)	0.429
No	167 (79.5%)	32 (84.2%	135 (78.5%)	
Season				
Fall (%)	53 (25.2%)	8 (21.1%)	45 (26.2%)	0.545
Winter (%)	48 (22.9%)	12 (31.6%)	36 (20.9%)	
Spring (%)	57 (27.1%)	10 (26.3%)	47 (27.3%)	
Summer (%)	52 (24.8%)	8 (21.1%)	44 (25.6%)	
Moon phase				
New (%)	51 (24.3%)	12 (31.6%)	39 (22.7%)	0.201
First quarter (%)	53 (25.2%)	10 (26.3%)	43 (25.0%)	
Full (%)	49 (23.3%)	4 (10.5%)	45 (26.2%)	
Last quarter (%)	57 (27.1%)	12 (31.6%)	45 (26.2%)	

[a]A *t*-test was used for the comparison of age by mortality status, with Welch's correction used to adjust for heterogeneity of variance.

analyses, with exponentiation back to the geometric mean with the 95% confidence interval (95% CI) reported as appropriate.

RESULTS

The mean age of the sample was 59.5 (±16.0) and 66% were male. A slight majority (52%) had only aortic dissection repaired compared with those who had other concomitant procedures, while 71% had hypertension, 6% had diabetes, 20% had dyslipidaemia and 1% had renal failure.

We focused on outcome following surgical repair as our primary study endpoint. Cross-sectional analyses examined the characteristics of those who died in surgery vs those who survived. Survivors were younger (58.1 ± 16.2 vs 65.9 ± 12.1, $P = 0.001$) and less likely to have diabetes (4.1 vs 13.2%, $P = 0.029$), but there were no statistically significant differences for sex, surgical group hypertension, dyslipidaemia, renal failure, weekend vs weekday admission, season or moon phase. Table 1 provides more detailed descriptive results on demographics and risk factors.

The full set of hypothesized covariates was entered into a multiple logistic regression analysis to examine for predictors of mortality. Age (odds ratio [OR] = 1.04, 95% CI = 1.01–1.07, $P = 0.012$) and a surgical procedure conducted in the full-moon phase (OR = 0.21, 95% CI = 0.05–0.81, $P = 0.024$) were both predictive of mortality status controlling for all other covariates, with older patients more likely to die and those who had surgery during the full-moon phase vs the new moon reference category less likely to die. Table 2 provides greater detail on the full model with all the covariates.

We also examined the set of covariates with respect to their bivariate relationship with the hospital LOS among survivors after the surgical procedure. The overall average LOS in days was highly skewed and kurtotic, procedure was significant ($P = 0.030$) with those having repair of aortic dissection only having and a natural log transformation was applied to this variable for all analyses in which it was examined. Exponentiation of the log transformed LOS value across the whole sample describes a geometric mean LOS of 13.4 days (95% CI 12.0–15.0). Among hypothesized predictors of LOS, the type of surgical procedure was significant ($P = 0.030$), with those having repair of aortic dissection only having a longer geometric mean LOS of 15.1 days (95% CI 12.8–17.8) versus 11.8 days (95% CI 10.2–13.7). An overall ANOVA, comparing the different moon phases during which a surgical procedure was done, was significant ($P = 0.018$) and a Tukey *post hoc* range test analysis indicated that procedures conducted during the full-moon phase had a significantly shorter LOS than those occurring during the first quarter, as well as having the overall lowest geometric mean LOS in days (10.2, 95% CI 8.3–12.5) in relation to the other moon phases. No other covariates were significantly related to LOS. A final multiple regression analysis was conducted in which the same set of covariates used in the multiple logistic regression were entered as predictors of the natural log transformed LOS. Surgical group ($P = 0.020$), and having a procedure conducted during the full-moon phase vs other moon phases ($P = 0.001$), remained significant in the regression model, while sex, that had not been statistically significant in a univariate analysis ($P = 0.11$), was also a significant predictor in the regression model ($P = 0.036$). The overall regression model with all covariates was significant ($F_{(14, 157)} = 1.965$, $P = 0.024$, multiple $R = 0.386$). See Table 3 for further details on the results of the regression analysis.

Table 2: Multiple logistic regression model predicting mortality status with regression coefficients and standard errors, *P*-values, odds ratios and their 95% CI

	B (SE)	*P*-value	Odds ratio	95% CI for odds ratio	
				Lower	Upper
Season[a]					
Winter	0.541 (0.553)	0.328	1.72	0.58	5.07
Spring	0.009 (0.559)	0.987	1.01	0.34	3.02
Summer	−0.180 (0.571)	0.753	0.84	0.27	2.56
Age	0.037 (0.015)	0.012	1.04	1.01	1.07
Sex[b]	−0.340 (0.420)	0.418	0.71	0.31	1.62
Hypertension	0.008 (0.491)	0.987	1.01	0.39	2.64
Diabetes	0.908 (0.708)	0.200	2.48	0.62	9.94
Renal failure	1.878 (1.623)	0.247	6.54	0.27	157.50
Dyslipidaemia	0.180 (0.481)	0.708	1.20	0.47	3.07
Weekend[c]	−0.408 (0.518)	0.431	0.67	0.24	1.84
Moon phase[d]					
First quarter	−0.247 (0.512)	0.629	0.78	0.29	2.13
Full	−1.584 (0.703)	0.024	0.21	0.05	0.81
Last quarter	−0.233 (0.493)	0.636	0.79	0.30	2.08
Surgical group[e]	0.092 (0.394)	0.816	1.10	0.51	2.37

[a]Reference category for each season is fall.
[b]Reference category is male.
[c]Reference category is weekday.
[d]Reference category for each moon phase is new moon.
[e]Reference category is patients having repair of ascending aorta only.

DISCUSSION

The mechanisms underlying ascending aortic dissections remain multifactorial. However, there are three major culprits: aortic wall weakening, intimal injury resulting in intravessel flap and

Table 3: Multiple regression model predicting natural log length of stay with unstandardized regression coefficients and standard errors, *P*-values and 95% CI for regression coefficients

Covariate	*B* (SE)	*P*-value	95% CI for *B*	
			Lower	Upper
Surgical group	−0.264 (0.109)	0.020	−0.487	−0.042
Sex	−0.264 (0.125)	0.036	−0.511	−0.018
Full moon	−0.536 (0.154)	0.001	−0.841	−0.232
New moon	−0.183 (0.159)	0.252	−0.0498	0.131
Last quarter	−0.166 (0.155)	0.284	−0.472	0.139
Age	0.007 (0.004)	0.071	−0.001	0.015
Hypertension	−0.091 (0.132)	0.492	−0.350	0.169
Diabetes	0.121 (0.289)	0.674	−0.448	0.691
Renal failure	0.950 (0.741)	0.202	−0.515	2.414
Dyslipidaemia	−0.251 (0.151)	0.099	−0.550	0.048
Weekend	−0.006 (0.139)	0.964	−0.281	0.268
Winter	0.119 (0.163)	0.468	−0.204	0.441
Spring	0.073 (0.155)	0.639	−0.233	0.378
Summer	0.044 (0.158)	0.778	−0.267	0.356

Multiple $R = 0.386$, multiple $R^2 = 0.149$, $F_{(14, 157)} = 1.965$, $P = 0.024$.

hypertension leading to the propagation of the intimal injury. Many cardiovascular risk factors related to seasonal variation have been investigated and include environmental (temperature and ultraviolet radiation), lifestyle (diet, obesity, exercise and smoking) and other, factors (blood pressure, serum cholesterol, glucose tolerance, coagulation, acute and chronic infections) [8, 9]. All such risk factors are more prevalent during the winter season, possibly contributing to a seasonal variation in deaths from AAD as well [10, 11]. A descriptive finding in our study is that the odds of death following AAD surgery during winter months were approximately twice as high as the odds of death following AAD surgery during the other seasons. One possible reason this finding did not reach statistical significance could be the lack of statistical power mostly due to an insufficient number of patients to adequately test for this potential relationship. Additionally, there may be an influential role played by other currently unknown and associated risk factors.

While several larger studies have demonstrated a seasonal variation event rate association with major cardiovascular diseases such as stroke, myocardial infarction and ascending aortic dissection [10–13], we are not aware of any studies regarding in-hospital clinical outcome following ADD repair in relation to the lunar cycle [14, 15].

In this study, risk-adjusted outcomes of AAD repair were better during the full-moon phase. This suggests that there is a possible role(s) for other chronobiological and meteorological variables. One such variable includes lunar cycle variation.

The lunar variation and its gravitational forces have generally been studied for associations with various outcomes throughout mankind's history and development. In a study of 1437 cases, the influence of the lunar cycle was associated with the incidence of cardiovascular emergencies presenting to the emergency room. Maximum deaths were associated with the first and last lunar quarters [16]. Data from 1999 to 2001 showed that there was an increased incidence of acute coronary events associated with new moon days ($P = 0.005$).

It is well known that the moon exerts a significant gravitational effect on earth throughout its 29.5-day revolution cycle. The existence of high and low tides is the direct consequence of this phenomenon. Some authors have postulated that this phenomenon as a plausible explanation for increased intracranial bleed with the new moon. In a retrospective review of 111 patients at a tertiary medical centre, an incidence peak for intracranial aneurysm was seen during the phase of the new moon ($P = 0.001$) [17]. However, akin to our study, they did not find any seasonal variation in the incidence of intracranial aneurysm rupture. While these observations remain interesting, possible mechanisms may be related to the influence of gravitational forces exerted by the moon on the earth and earth organisms, including the human body, with consequent changes in human behaviour during the lunar cycle, possibly influenced by gravitational forces acting on the neuroaxial system as well as other unknown factors. Although the gravitational force exerted by the moon on oceans may be significantly powerful to produce the high and low tides, its effect on minuscule objects such as human beings is estimated to be a rather small force by Newtonian Laws and is not well understood. While some studies have shown a correlation between the lunar cycle and cardiovascular disease, other studies have not [18, 19]. It is possible that the explanations already investigated for intracranial aneurysm rupture and stroke frequency could also apply to cardiac surgery. The stressful effect of surgical intervention could be more hazardous within a particular lunar phase cycle because of the altered disease behaviour seen in acute aortic dissection. However, the true underlying mechanisms for such remain elusive.

Our second study outcome was to determine any association with LOS after AAD for Groups A and B. We found that there was no statistical difference in the days following surgery repair among the seasons; however, there was a difference with statistically significant less LOS with the full moon, male gender and associated concomitant surgery. The lack of any significant association of LOS with year's season following AAD repair was not unexpected, given that postoperative intensive care unit management is run by fast-track protocols under the direct instruction of the attending physician as well as physician assistants. Our hospital has no residents or training house staff involved in postoperative routine patient care and discharge. Our study is in agreement with Buchwald *et al.* [20], who found no significant difference in LOS in 1251 patients hospitalized during the seasons with the 10 most prevalent medical and surgical diagnoses. Other factors could influence LOS, such as house staff experience and year of training. Rich *et al.* [21], analysing a larger sample of patients ($n = 5$, 240 467; 25 discharge diagnoses), showed that LOS, as well as house staff experience, increased and, perhaps surprisingly, that LOS after surgical intervention increased over the academic year.

STUDY LIMITATIONS

The data are limited to the two main hospitals that do more than 90% of cardiac surgery within the state of Rhode Island. We did not collect data on variables such as seasonal affective disorder, depression and their treatment, and these are therefore not used in our risk model [22]. It is also possible that there might be residual confounding of the relationship between mortality and LOS and season by other administrative and logistic variables. The overall number of patients also represented within the different lunar cycle phases created some small cell sizes, and this effect warrants further examination within a larger sample of patients.

In conclusion, AAD repair performed in the waning full moon appeared to reduce the odds of death, and a full moon was associated with shorter LOS; however, the small cell sizes for the levels of the lunar cycle warrant a further examination of this finding to rule out chance.

Conflict of interest: none declared.

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