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Brief Report

Impact of weather on the risk of surgical site infections in a tropical area

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We studied the impact of average daily temperature and relative humidity on the risk of surgical site infections in 36,429 surgeries performed in a hospital in inner Brazil. Adjusted Poisson regression models found an association between surgical site infections and temperature (rate ratio [RR], 1.013; 95% confidence interval [CI], 1.001-1.025). The effect was concentrated on clean wound procedures and was greater over the 75th (RR, 1.109; 95% CI, 1.015-1.212) and 90th (RR, 1.196; 95% CI, 1.055-1.355) percentiles of daily temperature.

The impact of climate, seasons, and weather on health care–associated infections (HAIs) was recently acknowledged.[1] This finding added novel determinants to the epidemiology of HAIs, with possible implications for infection prevention and control. However, most studies focusing on that association were conducted in hospitals located in temperate latitudes.

In the tropics, there are differences that deserve investigation. First, seasons are not as well characterized as in temperate climates. Furthermore, climate control in hospitals is often absent or incomplete.[2] Finally, a recent study found a greater incidence of gram-negative infections associated with proximity to the equator.[3]

There is some evidence of seasonality for surgical site infections (SSIs).[4] Given the burden of those infections in Brazil,[5] and with the aim of fulfilling a gap in evidence for tropical settings, we investigated the seasonality and the impact of meteorologic conditions on the incidence of SSIs in a teaching hospital in that country.

METHODS

The study was conducted in the teaching hospital from Faculdade de Medicina de Botucatu (Botucatu Medical School), a 450-bed facility located in inner São Paulo State, Brazil (22°53′21"S, 48°29′ 40"W). In that hospital, there is climate control in the operating rooms and intensive care units but not in wards for noncritical patients. We studied a cohort of patients who underwent surgical procedures in the years 2011-2016.

Demographic data, time from admission to surgery, wound classification, and surgical specialty were recorded. Daily average temperature and relative humidity, as well as rainfall, were collected from a nearby meteorologic station (Faculty of Agronomical Sciences, City of Botucatu, Brazil). Data on SSIs were obtained from active surveillance, both in-hospital and after discharge, according to a validated protocol.[6]

Time trends of monthly SSI rates were analyzed with linear regression, whereas seasonality was tested in Box-Jenkins autoregressive integrated moving average models and autocorrelation plots.[7] We used Poisson regression models for 2 kinds of analysis: (1) testing for an association of aggregated incidence for months or seasons and (2) testing for an association of daily meteorologic parameters and the risk of SSIs for individual patients. These latter models were adjusted for demographics, wound classification, and surgical specialty. In alternative models, temperature and humidity values were dichotomized at the 75th and 90th percentiles. All tests were performed using SPSS version 20 (IBM, Armonk, NY) and NCCS9 (LLC, Kaysville, UT). The study was approved by the local Committee for Ethics in Research.

RESULTS

The study cohort comprised 36,429 patients from 13 different surgical specialties. The overall incidence of SSIs was 8.4%. The most frequent procedures and respective SSI rates were open reduction of

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fractures (4,458, 5.2%), cesarean section (4,028, 10.3%), hernia repair (1,487, 5.3%), craniectomy (1,350, 7.9%), and laparotomy (1,138, 15.1%). Among clean procedures, the list included (in addition to open reduction of fractures, hernia repair, and craniectomy) breast surgery (1,117, 6.2%) and spinal surgery (699, 7.2%). Additionally, the greatest infection rates were detected for procedures involving the liver/pancreas (20.8%), the small bowel (19.6%), member amputation (19.3%), the colon (18.8%), and laparotomy (15.1%). Among the overall 3,049 SSIs, 65.8% were classified as superficial, 29.0% as deep, and 5.2% as organ/space.

There was an overall trend for reduction of monthly incidence rates during the study period (r = −0.53; $P < .001$). We did not find significant seasonality or greater incidence in specific months or seasons. However, there was an associated increased individual risk of SSIs with average temperature and humidity on the day when the surgery was performed (Table 1). The effect of temperature was concentrated in clean wound procedures (rate ratio [RR] = 1.020; 95% confidence interval [CI], 1.001-1.039; $P = .03$), whereas the association with humidity reached marginal significance for clean-contaminated wounds (RR = 1.045 for relative humidity [×10]; 95% CI = 0.999-1.094; $P = .05$). Overall, the impact of temperature on the risk of SSIs increased when values were dichotomized at the 75th and 90th percentiles (Table 2).

DISCUSSION

In addition to seasonality, the impact of environmental temperature on the risk of SSIs has been described. Studying a large national database from the United States, Anthony et al[8] reported that monthly SSI rates increased by 2.1% per 2.8°C (5°F) rise in average temperature. Coherently, we found an increase of 1.3% in the individual risk of SSI per each degree Celsius of rise in average temperature on the day when the surgery was performed. That increase reached nearly 20% when the temperature was >24.7°C (76.5°F).

Several doubts remain about the mechanisms underlying the association between summer (or high temperatures) and SSIs. An analogy has been made regarding the greater incidence of skin and soft tissue infections during warmer and more humid periods.[9] Increases in bacterial population, skin-to-skin contact, disruption of the tegument, and traumatic wounds during summer have been blamed.[4] Finally, Manian[10] suggested that excessive perspiration and suboptimal skin hygiene are more likely to occur during summer. Considering that the effect of temperature in our study was concentrated in clean wound procedures, we agree that ecological changes (either quantitative or qualitative) in the skin microbiome play a role in increasing the risk of SSIs. However, the trend for an association between higher humidity and infection in clean-contaminated wounds in our study remains puzzling.

The absence of seasonality in our findings may be owing to the irregularity of seasons in the tropical climate. It is, however, worth noting that we could rule out the impact of surgeon skill and experience, because we did not find increased rates of SSI in March and April, which were the initial months of surgical training in our teaching hospital.

Our study has some limitations. First, it is set in a single center. In addition, our database did not include information on subjects' comorbidities. The fact that an extensive effort of the infection control team to reduce SSIs, including strict recommendations for timing of antimicrobial prophylaxis, restriction of hair removal, and improvements in preoperative care (reflected in downward trends), was counterbalanced by a slight increase in daily average temperature over time (r = 0.05; $P = .01$), which may have underestimated the association between temperature and infection. Finally, the relatively small time span (2011-2016) of the study may have prevented us from identifying seasonality. However, we enrolled many surgical procedures, assigning daily values of temperature, humidity, and rainfall to each one. Although one may argue that the study was conducted in a tropical country without great variation of temperature over the year (and therefore could be applicable to similar settings), we believe, on the basis of our findings and previous studies,[4,8,10] that even greater impact can occur in climates with extremes of cold and hot weather.

In conclusion, we found a consistent association between temperature and the individual risk of SSI. That association was concentrated in clean wound procedures and was especially strong for extreme temperature values.

Table 1
Multivariable Poisson regression model of factors associated with risk of surgical site infections in the study hospital

Factors	Adjusted RR (95% CI)	*P*
Meteorology		
Temperature (°C)	**1.013 (1.001-1.025)**	**.03**
Relative humidity (×10%)	**1.032 (1.001-1.064)**	**.04**
Rainfall (mm)	0.998 (0.994-1.002)	.25
Year of surgical procedure		
2011 (reference)	—	—
2012	0.917 (0.80-1.05)	.22
2013	1.082 (0.94-1.25)	.28
2014	0.877 (0.76-1.01)	.07
2015	**0.753 (0.65-0.88)**	**<.001**
2016	**0.725 (0.62-0.84)**	**<.001**
Wound classification		
Clean (reference)	—	—
Clean contaminated	**1.57 (1.03-2.39)**	**.036**
Contaminated	**2.18 (1.28-3.70)**	**.004**
Dirty	**2.76 (1.82-4.20)**	**<.001**
Days of admission before surgery	**1.02 (1.01-1.02)**	**<.001**
Demographic data		
Age (y)	**1.002 (1.001-1.004)**	**.004**
Male sex	0.99 (0.92-1.08)	.90

NOTE. The model was adjusted for surgical specialty. Significant ($P < .05$) results are presented in boldface type.
CI, confidence interval; *RR*, rate ratio.

Table 2
Results of the Poisson models when temperature or humidity values are dichotomized at the 75th or 90th percentile

Parameter	Temperature	Relative humidity
75th percentile	**22.9°C**	83.1%
Adjusted RR (95% CI)	**1.109 (1.015-1.212)**	1.016 (0.925-1.116)
P	**.02**	.74
90th percentile	**24.7°C**	90.5%
Adjusted RR (95% CI)	**1.196 (1.055-1.355)**	0.999 (0.995-1.003)
P	**.005**	.85

NOTE. Models were adjusted for all variables listed in Table I. Significant ($P < .05$) results are presented in boldface type.
CI, confidence interval; *RR*, rate ratio.

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