

The Correlation between Cholecystectomy and Seasonal Impact in Taiwan

Chi-Ming Liu^{1,2}, Chung-Te Hsu³, Tsai-Ling Liu², Nicole Huang⁴, Pesus Chou⁵,
and Yiing-Jenq Chou⁵

¹Department of Medical Research and Education, Division of General Surgery
Cheng-Hsin General Hospital, Taipei 11220

²Institute of Public Health, National Yang-Ming University, Taipei 11221

³Division of Gastroenterology, Cheng-Hsin General Hospital, Taipei 11220

⁴Institute of Hospital and Health Care Administration, National Yang-Ming University, Taipei 11221
and

⁵Institute of Public Health, National Yang-Ming University, Taipei 11221, Taiwan, Republic of China

Abstract

Many diseases and illnesses are known to be induced by changes in season and have seasonal fluctuations, and are affected by meteorological factors. Cholecystectomy is a very common surgical procedure used to treat gallstone disease and related complications. This study aimed to examine possible impacts of the seasons on the incidence of cholecystectomy with respect to gender and age as well as whether meteorological variables showed an association with incidences of cholecystectomy. The study was retrospectively conducted using the nationwide population-based datasets of National Health Insurance System in Taiwan. Patients who had undergone cholecystectomy were identified according to the International Classification of Diseases version 9 codes and categorized in terms of age and gender. Autoregression integrated moving average (ARIMA) multivariate models were applied to investigate the association of cholecystectomy incidence rates, time and meteorological variables. A total of 192,833 patients who underwent cholecystectomy between 1996 and 2008 were identified for the analysis. A trend indicating an overall increase was observed for the incidence rate of cholecystectomy over the study period. There were more females who underwent cholecystectomy than males. The highest incidence was found to occur during the summer and the lowest during the winter correlating with the cyclic pattern of temperature in Taiwan. Overall, the cholecystectomy incidence rate increased steadily over the 13-year study period for all age groups. In conclusion, the incidence of cholecystectomy was found to be correlated with the seasons. Temperature is the most notable variable among the relevant meteorological factors. Culture may also play a role in these correlations.

Key Words: cholecystectomy, cholecystitis, culture, gallstone, seasonal impact

Introduction

Human health is influenced by weather changes in terms of creating a climate favorable to and conditions suitable for proliferation and transmission of pathogens. Severe weather can affect the timing and the frequency of mortality and the presence of outbreaks of infectious diseases. Host susceptibility,

periodic changes in pathogen abundance and variations in transmissibility are all involved in the manifestation of various diseases with respect to seasonal variations. The ever-changing environment also plays a role in supporting or repressing the presence of a host or pathogen. Marked seasonal fluctuations, including temperature, humidity, and rainfall, which affect pathogenic mechanisms, have been noted and

Corresponding author: Dr. Yiing-Jeng Chou, Professor, Institute of Public Health, National Yang-Ming University, No. 155, Sec. 2, Li-Nong St., Beitou District, Taipei 11221, Taiwan, R.O.C. Tel: +886-2-28267107, Fax: +886-2-28261002, E-mail: yjchou@ym.edu.tw.

Received: November 30, 2012; Revised: April 29, 2013; Accepted: July 1, 2013.

©2014 by The Chinese Physiological Society and Airiti Press Inc. ISSN : 0304-4920. <http://www.cps.org.tw>

documented by scientists worldwide and these factors have been shown to result in fluctuations in the frequency of many diseases.

Seasonal changes have a significant effect on gastrointestinal diseases such as duodenal ulcer (4, 6, 34) as well as other diseases including depression (10), heat exhaustion and mortality (13). Effective strategies to prevent the spread of an emerging infection and to control the occurrence of a disease necessitate insights into the cyclic nature of diseases. Time-series analysis has been applied in econometrics for many years, particularly in forecasting; in recent years, it has also been extensively used to study the effects of environmental exposure. Auto-regression integrated moving average (ARIMA) models have provided useful tools when analyzing non-stationary time-series data that include ordinary and seasonal trends (5, 32).

Cholecystectomy is the most common surgical procedure used to treat gallstone disease (GSD), which is one of the most prevalent and costly digestive illnesses. Prevalence rates range from 10% to 15% for European and American populations and from 3% to 10% for African and Asian populations. More than 80% of gallstone carriers are asymptomatic, and it has been estimated that 1% to 2% of patients per year develop gallstone symptoms and/or complications lead to the need for surgical intervention (23, 31). Symptoms and complications associated with GSD that causes clinical manifestations result in a need for cholecystectomy or antibiotic treatment when there is inflammation of the gallbladder (acute and chronic cholecystitis) and/or inflammation of the common bile ducts (choledocholithiasis, cholangitis, and biliary pancreatitis). The clear benefits of laparoscopic cholecystectomy (LC) over open cholecystectomy (OC, or traditional) have been reported in a number of previous studies; these advantages have made this procedure the gold standard for the treatment of GSD and associated complications (12, 16, 21). This is primarily because LC results in reduced hospital stay time, lower total costs for the procedure, less postoperative pain, and fewer postoperative complications together with higher patient satisfaction (3, 14). The safety of LC, when used to treat elderly patients, has also been confirmed in many studies. LC is now the preferred method for cholecystectomy (16, 29), which is also one of reasons why there have been an increasing number of cholecystectomies carried out in Taiwan.

Taiwan is in the subtropical region with relatively high humidity throughout the year and the country has maximum rainfall during the May to July period. Seasonal variations in disease onset and hospital admission have been observed in Taiwan for psychiatric cases, respiratory diseases, peptic ulcers, duodenal

ulcers and gastric ulcers (17, 30, 34). In this context, it has been considered that meteorological variables are associated with variations in disease frequencies, but there is very limited information available that describes the relationship between abdominal surgery events and climatic factors. As far as we know, there seems to be a spontaneous seasonal gallstone cycle in animals and this may be associated with various physiological and nutritional factors (9). However, no study using a substantial population has ever been attempted to investigate the seasonality of human GSD and the related incidences of cholecystectomy and/or the association of GSD with climate. In the present study, a 13-year nationwide population-based dataset (1996-2008) obtained from the Taiwan National Health Insurance System was used. The aim of this study was to examine possible impact of seasonal variations on the incidence of cholecystectomy across the genders and different age groups. The association between incidences and meteorological variables was also analyzed.

Materials and Methods

Source of Data

This retrospective cross-sectional and population-based study was conducted by data-mining of the database of the Bureau National Health Research Institute (BNHI) and the National Health Research Institute (NHRI) of Taiwan. The BNHI is the national health insurance provider covering approximately 99% of the 23 million residents of Taiwan (33). The comprehensive computerized datasets consist of continuous input from the pharmaceutical, medical and administrative systems of hospitals/practitioners in Taiwan, and are available to investigators for research purposes. Information on inpatient visits includes ID, gender, date of birth, dates of admission and discharge, clinical diagnosis and treatment codes; the information can be obtained after individual health information has been encrypted to ensure privacy. Other similar epidemiological studies have used these datasets to facilitate their studies.

Meteorological data were obtained from the 26 Central Weather Bureau (CWB) observatories in Taiwan*. Mean monthly values were calculated using daily records of ambient temperature (°C), relative humidity (%), atmospheric pressure (hPa) and hours of sunshine (h).

Data Collection

We collected the ambulatory care visits and hos-

*Website of Central Weather Bureau: <http://www.cwb.gov.tw/eng/index.htm>

pitalization claims data that involved possible episodes of gallstones or common bile duct stones from the NHRI datasets under the NHRI Database (NHRID) project[#]. The patients with a principal diagnosis of cholecystitis and its related complications (The International Classification of Disease, 9th Revision, Clinical Modification, ICD-9-CM code 574.xx and 571.1x) that were captured during the period between 1996 and 2008 were used in this investigation. A total of 194,518 patients undergoing cholecystectomy formed the initial dataset for this study. Patients with incomplete demographic information ($n = 1,147$) were excluded. In addition, patients aged ≤ 20 years ($n = 538$) were also excluded because the numbers in this group were relatively small for statistical and comparative purposes. Therefore, in total, 192,833 patients were enrolled and the information on their age, gender and year of admission was collected. The background and baseline characteristics of these patients, such as body mass index (BMI) and comorbidities, were not available for the final analysis.

The CWB defines spring as March to May, summer as June to August, autumn as September to November, and winter as December to February (34), with maximum humidity occurring from May to July. The meteorological variables assessed included the maximum, minimum and mean ambient temperature ($^{\circ}\text{C}$), relative humidity (%), atmospheric pressure (hPa) and hours of sunshine (h). Monthly means of the daily averages of all the measurements were used in this study.

Statistical Analysis

The independent variables included in this study were the patient's age and gender, together with the monthly mean values for temperature, humidity and duration of sunshine from 1996 to 2008 in Taiwan, as well as other meteorological information. The percentages of cases where cholecystectomy was applied to treat GSD-related cholecystitis and complications were considered to be dependent variables. Monthly rates of hospital admission for cholecystectomy per 100,000 persons in the population were calculated across the 13-year study period (156 months, between 1996 and 2008) and were categorized into gender and various age groups, namely 20-34, 35-49, 50-64, 65-79, and ≥ 80 years.

ARIMA multivariate models were fitted to the dependent and independent variables and applied to investigate the relationship between the incidence of cholecystectomy and various time series. The time trend for each month and the various meteorological variables (monthly mean values of ambient tempera-

Table 1. Descriptive statistics for cholecystectomies in different age groups and genders groups in Taiwan in the period 1996-2008

	n	%
No. of Patients	192 833	
Year		
1996	10 206	5.29
1997	11 859	6.15
1998	12 836	6.66
1999	13 610	7.06
2000	14 719	7.63
2001	15 906	8.25
2002	16 060	8.33
2003	14 473	7.51
2004	15 779	8.18
2005	15 300	7.93
2006	16 127	8.36
2007	17 220	8.93
2008	18 738	9.72
Age		
20-34	16 841	8.73
35-49	47 297	24.53
50-64	57 746	29.95
65-79	56 080	29.08
≥ 80	14 869	7.71
Gender		
Male	88 030	45.65
Female	104 803	54.35

ture, relative humidity, atmospheric pressure and hours of sunshine) were evaluated across all age groups. January was used as the reference month and the calendar months were dummy variables. The goodness-of-fit of the ARIMA models was measured using the Akaike Information Criterion (AIC) and the Schwarz Criterion (SC) approaches. Lower AIC/SC values indicated a better goodness-of-fit with a minimization of the loss of information during the data-generating process (27).

All analyses were conducted using the SAS for Windows, Version 9.2 (SAS Institute Inc., Cary, NC, USA) and EViews (Quantitative Micro Software version 6.0) statistical software packages. A P value of less than 0.05 was considered to be statistically significant.

Results

A total of 192,833 incidents involving hospital admission were found to have required cholecystectomy procedures for GSD-related cholecystitis and complications; these patients were identified and analyzed. The number of patient and the corresponding percent-

[#]Website of National Health Insurance Research Database: <http://nhird.nhri.org.tw/en/>

Table 2. Monthly means rates for cholecystectomies and various meteorological values in Taiwan in 1966-2008

Variable	Monthly Mean	SD	Minimum	Maximum
Cholecystectomy/100,000 by Gender				
Male	6.88	1.13	3.38	10.32
Female	8.38	1.42	3.68	12.63
Total	7.62	1.25	3.53	11.24
Cholecystectomy/100,000 by Age Group (yrs)				
20-34	1.92	0.62	0.59	3.67
35-49	5.57	1.14	2.55	9.15
50-64	12.19	2.04	4.56	16.92
65-79	21.51	3.19	11.95	30.13
≥ 80	26.11	4.21	14.40	35.97
Meteorological Factors				
Ambient Temperature (°C)	23.8	4.1	15.8	30.1
Relative Humidity (%)	76.4	3.0	66.1	82.9
Atmospheric Pressure (hPa)	1009.0	5.0	999.6	1017.4
Sunshine (h)	154.0	39.7	64.9	283.9

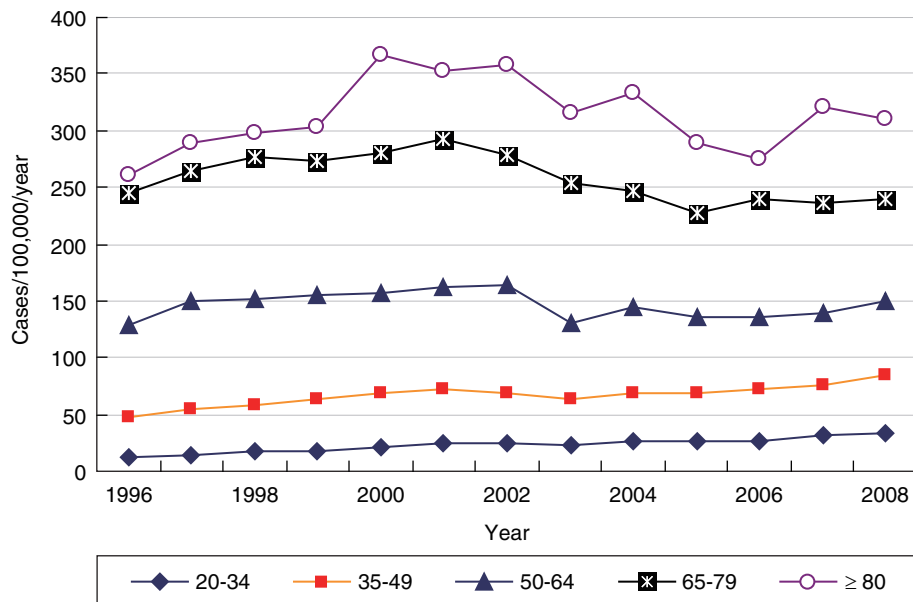


Fig. 1. Incidences of cholecystectomy in Taiwan, 1996-2008, in various age groups over the 13-year study period.

ages for each year for the period between 1996 and 2008 are summarized in Table 1. A trend towards an overall increase can be observed for the cholecystectomy incidence rate over the study period. About 85% of cholecystectomies involved patients who were aged from 35 to 79 years. More females underwent cholecystectomy than males (54.35% vs. 45.65%), with the rates being 8.38 and 6.88 per 100,000 individuals, respectively (Table 2). A steady increase in the incidence rates with advancing age was observed. Accordingly, the monthly mean incidence rates for cholecystectomy were 1.92, 5.57, 12.19, 21.51, and 26.11 per 100,000 subjects for the groups aged 20-34, 35-49,

50-64, 65-79, and ≥ 80 years old. A steady rise in incidence of cholecystectomy across all age groups was also observed over the 13-year study period (Fig. 1).

The collected meteorological data for the period 1996-2008 is summarized in Table 2. The average temperature was 23.8°C. In addition, the average temperature was 18.3°C during winter, 23.2°C during spring, 28.4°C during summer, and 25.1°C during autumn. Furthermore, the maximum monthly temperature also varied widely, from 22.4°C in the winter to 34.8°C in the summer. The minimal monthly temperatures ranged from 14.2°C to 22.2°C. The monthly mean values for SD relative humidity and atmospheric

Table 3. Crude correlations between the various climatic factors and the monthly cholecystectomy incidence rates in Taiwan, 1996-2008

	Ambient Temperature (°C)	Relative Humidity (%)	Atmospheric Pressure (hPa)	Sunshine (h)
Gender:				
Male	0.414***	-0.146	-0.336***	0.335***
Female	0.401***	-0.133	-0.285***	0.347***
Age Group (years):				
20-34	0.254**	-0.222**	-0.268**	0.245***
35-49	0.387***	-0.162*	-0.260**	0.350***
50-64	0.417***	-0.035	-0.354***	0.328***
65-79	0.374***	0.083	-0.272**	0.247***
> 80	0.290***	0.015	-0.066	0.218***
Overall	0.414***	-0.143	-0.309***	0.349***

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

Table 4. ARIMA regression analysis of the impact of gender, seasonal factors and meteorological factors on the incidence of cholecystectomy inpatients per 100,000 individuals in Taiwan, 1996-2008

Independent Variables	Male			Female			Overall		
	β	SE	t Value	β	SE	t Value	β	SE	t Value
Intercept	-27.48	31.85	-0.86	-101.73	47.15	-2.15*	-0.753	7.342	-0.10
AR1	0.467	0.076	6.13***	0.434	0.080	5.42***	-0.953	0.032	-29.77***
MA2	0.508	0.075	6.79***	0.348	0.087	4.02***	-0.995	0.000	-34.80***
Temperature (°C)	0.086	0.054	1.58	0.168	0.079	2.12*	-0.004	0.019	-0.19
Pressure (hPa)	0.030	0.031	0.97	0.103	0.046	2.24*	0.001	0.007	0.06
Sunshine (h)	0.003	0.002	-1.80	-0.003	0.002	-1.38	-0.002	0.000	-6.73***
February	-0.513	0.166	-3.09*	-0.962	0.221	-4.35***	-0.124	0.316	-0.39
March	0.363	0.213	1.70	0.360	0.300	1.20	1.579	0.283	5.57***
April	0.006	0.344	0.02	0.008	0.487	0.02	0.434	0.270	1.60
May	0.096	0.444	0.22	-0.087	0.640	-0.136	0.570	0.318	1.79
June	-0.015	0.510	-0.03	-0.086	0.743	-0.12	0.610	0.315	1.94
July	0.954	0.551	1.73	1.350	0.809	1.67	1.811	0.352	5.14***
August	0.334	0.541	0.62	0.297	0.794	0.37	-0.157	0.325	-0.48
September	0.477	0.491	0.97	0.547	0.714	0.77	0.900	0.332	2.71**
October	0.715	0.397	1.80	0.887	0.571	1.55	0.965	0.283	3.41**
November	0.548	0.282	1.94	0.592	0.406	1.46	0.278	0.266	1.05
December	0.415	0.185	2.24*	0.346	0.252	1.38	0.059	0.307	0.19
AIC		1.433			2.066			1.479	
SC		1.766			2.400			1.815	
R ²		0.640			0.587			0.691	

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

AR1, autoregressive lag 1; MA 2, moving average lag 2.

pressure were 76.4% and 1009.0 hPa, respectively. The highest humidity and the lowest atmospheric pressure occurred during summer. In contrast, the lowest humidity and the highest atmospheric pressure occurred during winter. The monthly mean sunshine level was 154 h, with a mean of 6.4 h/day in summer and of 4.1 h/day in winter. An initial analysis of the correlations between the incidence of cholecystectomy and the various climatic factors showed significant

correlation for temperature, pressure and sunshine across all age groups and in both genders (Table 3). There was a consistent cyclic variation in cholecystectomy rates that correlated with temperature, atmospheric pressure and sunshine over the 13-year study period (Fig. 2). Specifically, the cyclic pattern in temperature was highly correlated with the cholecystectomy rate (Fig. 2A); however, the impacts of pressure and sunshine (Fig. 2, B and C) were not significant.

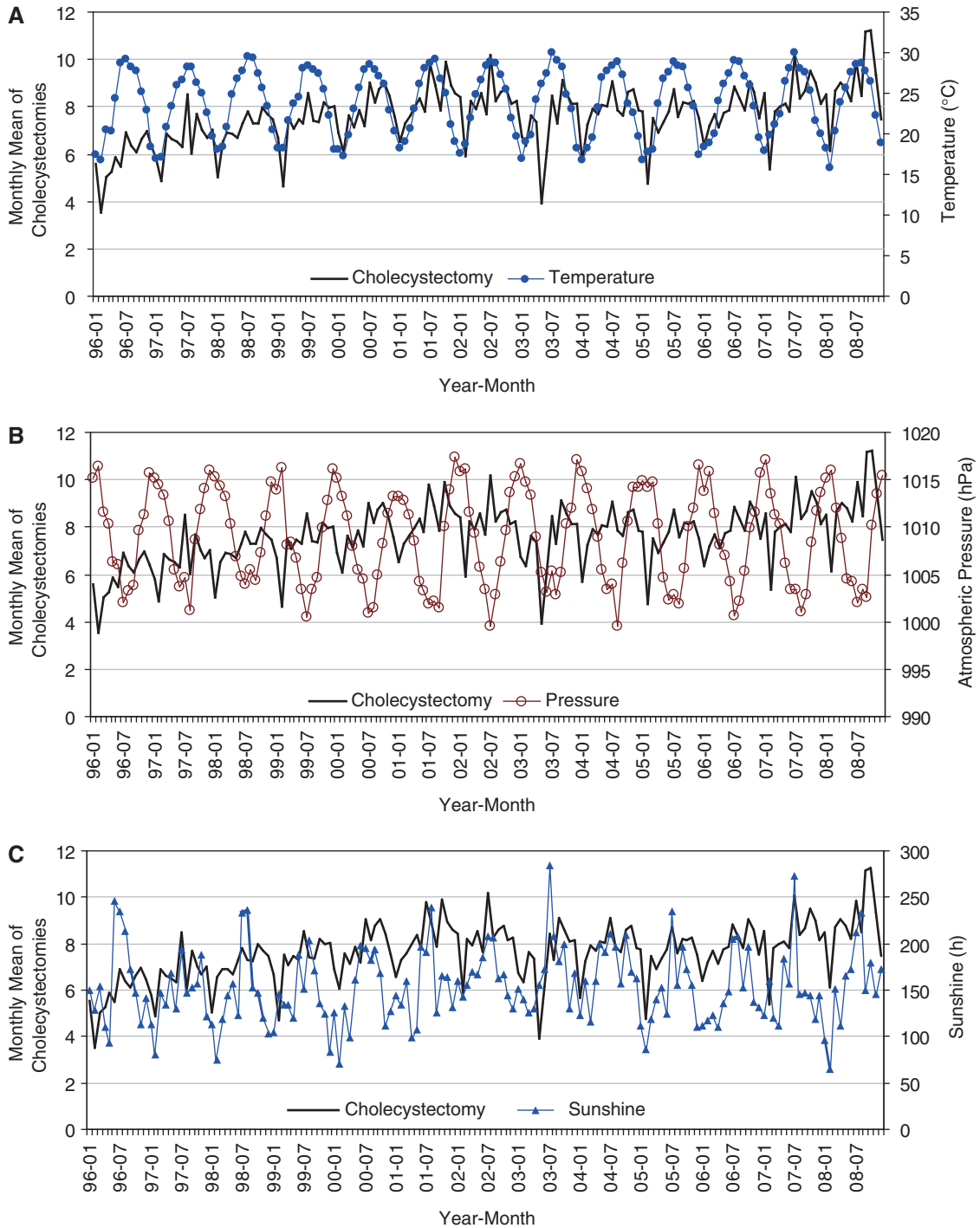


Fig. 2. Time series of the incidences of cholecystectomy and various meteorological variables including mean monthly temperature (A), atmospheric pressure (B), and sunshine (C) in Taiwan, 1996-2008.

To determine the association of cholecystectomy with climatic variables in temperature, pressure and sunshine, an analysis using ARIMA models was performed to distinguish specific effects of the climatic variables and the calendar months. Females subjects were more sensitive to changes in temperature and pressure than the males subjects (Table 4). Females

were more likely to be affected by atmospheric pressure but were less impacted by sunshine than males. Notably, seasonal trends in monthly incidence of cholecystectomy resulted in a decrease during February, which was followed by a significant increase for March ($P < 0.001$). The highest incidence occurred in July ($P < 0.001$), which was followed by a significant re-

Table 5. ARIMA regression analysis of the impact of seasonal factors and meteorological factors on the incidence of cholecystectomy in different age groups (per 100,000 individuals) in Taiwan, 1996-2008

Independent Variables	Age 20-34 years			Age 35-49 years			Age 50-64 years			Age 65-79 years			Age ≥ 80 years		
	β	SE	t Value	β	SE	t Value	β	SE	t Value	β	SE	t Value	β	SE	t Value
Intercept	-18.87	20.58	-0.92	-9.586	48.84	-0.20	-66.52	97.57	-0.68	-339.5	143.2	-2.37**	-124.1	269.9	-0.46
AR1	-0.700	0.064	-10.89***	-0.596	0.078	-7.66***	0.567	0.084	6.72***	0.805	0.057	14.05***	0.460	0.087	5.29***
SAR12	0.186	0.179	1.04	-0.367	0.097	-3.78***	0.206	0.249	0.83	-0.643	0.072	-8.87***	0.427	0.155	2.77**
MA12	-0.915	0.029	-31.49***	-0.938	0.020	-47.73***	-0.918	0.038	-24.28***	0.951	0.015	62.76***	-0.905	0.039	-23.49***
SMA12	0.256	0.187	1.37	0.918	0.019	47.41***	0.130	0.245	0.53	-0.957	0.018	-53.85***	0.120	0.168	0.72
Temperature (°C)	0.026	0.032	0.81	0.060	0.078	0.77	0.168	0.159	1.06	0.310	0.211	1.47	0.373	0.433	0.86
Pressure (hPa)	0.009	0.008	1.04	0.016	0.018	0.88	0.062	0.047	1.31	0.325	0.066	4.90***	0.256	0.128	1.99**
Sunshine (h)	0.017	0.020	0.87	0.007	0.047	0.15	0.068	0.095	0.72	0.323	0.139	2.32**	0.123	0.261	0.47
February	-0.159	0.113	-1.40	-0.612	0.182	-3.36***	-1.295	0.233	-5.56***	-2.236	0.269	-8.31***	-3.796	0.755	-5.03***
March	0.814	0.103	7.88***	1.315	0.228	5.76***	1.103	0.524	2.10**	2.530	0.703	3.60***	1.092	1.490	0.73
April	-0.094	0.214	-0.44	-0.193	0.471	-0.41	0.334	1.046	0.32	1.618	1.412	1.15	-1.597	2.858	-0.56
May	0.183	0.287	0.64	-0.268	0.652	-0.41	0.250	1.508	0.17	1.449	2.057	0.70	-2.113	4.067	-0.52
June	0.294	0.343	0.86	-0.078	0.775	-0.10	-0.276	1.784	-0.15	1.600	2.431	0.66	-2.265	4.781	-0.47
July	0.429	0.377	1.14	1.524	0.858	1.78	2.840	2.000	1.42	5.073	2.731	1.86	0.419	5.359	0.08
August	-0.098	0.373	-0.26	-1.267	0.843	-1.50	0.601	1.955	0.31	2.511	2.676	0.94	-2.189	5.229	-0.42
September	0.198	0.323	0.61	-0.401	0.736	-0.55	1.481	1.702	0.87	3.741	2.308	1.62	-0.067	4.582	-0.01
October	0.190	0.254	0.75	0.544	0.572	0.95	2.804	1.288	2.18**	5.826	1.727	3.37**	0.160	3.497	0.05
November	0.131	0.161	0.81	-0.329	0.373	-0.88	2.252	0.832	2.72**	4.038	1.097	3.68***	-0.413	2.296	-0.18
December	-0.056	0.116	-0.48	-0.051	0.205	-0.25	1.644	0.343	4.80***	2.683	0.438	6.13***	-0.719	1.085	-0.66
AIC		0.337			1.844			3.438			4.391			5.327	
SC		0.732			2.240			3.832			4.785			5.721	
R ²		0.664			0.711			0.599			0.584			0.341	

** $P < 0.01$; *** $P < 0.001$.

AR1, autoregressive lag 1; SAR12, seasonal correlation lag 12; MA12, moving average lag 12; SMA12, seasonal moving average lag 12.

duction in August. An upward trend then started from September or October ($P < 0.01$), which was followed by a slow decrease over the next few months. The overall lowest incidence rate was encountered during winter.

The impact of seasonal and meteorological factors on monthly incidence of cholecystectomy in different age groups was also analyzed by AMIRA and is shown in Table 5. Elevated ambient temperature was associated with an increased incidence of cholecystectomy across all age groups. The increase per degree Celsius change were 0.026, 0.06, 0.168, 0.310 and 0.373 events per 100,000 individuals for the groups aged 20-34, 35-49, 50-64, 65-79 and ≥ 80 years, respectively. The incidence of cholecystectomy was also significantly associated with an increased atmospheric pressure for the age groups 65-79 and ≥ 80 years ($P < 0.001$ and $P < 0.01$, respectively). It was noted that patients aged more than 65 years were more sensitive to all three types of climatic changes, namely temperature, atmospheric pressure and sunshine. The seasonal pattern for the incidence of cholecystectomy across the different age groups was fairly similar when the two genders were analyzed separately (Table 4).

Discussion

A total of 192,833 patients over 13 years (from

1996 to 2008) underwent cholecystectomy following a diagnosis of cholecystitis and GSD-related complications; these patients were identified and enrolled in the study. There was an overall increase trend in the incidence of cholecystectomy across all age groups over the study period. The finding that the incidence of cholecystectomy among females is higher than males is consistent with previous observations of higher prevalence of GSD among women (1). The average monthly incidence rates per 100,000 individuals increased with advancing age. According to data sourced from National Statistics, ROC (TW), the average age of the population is continuing to rise in a manner similar to that in western countries. Thus, the incidence of elderly patients with symptomatic gallstones is likely to continue to increase and the incidence of cholecystectomy incidence is, therefore, also likely to increase annually as shown by the present study.

LC has become the preferred method of treatment for symptomatic GSD rather than OC over the past 15 years because of shorter hospital stay, fewer postoperative complications, earlier recovery, and the ability of the patient to regain a good quality of life (18, 26). The treatment trends with respect to GSD are specifically an increase in LC treatment, which is paralleled by fewer OC treatments. However, the prevalence of GSD and incidence of cholecystectomy are unlikely to be influenced by surgical technology used.

Instead, the superior results with LC have changed the management strategy for cholecystitis, with an appreciable numbers of early cholecystectomy being performed as soon as the patient can be prepared.

The meteorological variables display a clear association with the incidence of cholecystectomy. Temperature seems to play a significant role in the occurrence of cholecystitis in Taiwan, which is consistent with a previous study reporting acute cholecystitis as being higher in the summer compared to other seasons (15). In addition, subjects aged ≥ 65 years are more sensitive to changes in temperature and pressure, and females are also more susceptible than males. Exposure to heat or cold constitutes the most common direct cause of most acute illnesses and death (11, 25). It has been suggested that temperature-related seasonal variations are associated with kidney stone formation (8) and urinary calculi attacks (7, 20). Furthermore, epidemiological studies have demonstrated that, regardless of race or gender, individuals older than 65 years and young children in particular show vulnerability to the adverse effects of heat and high temperature than young adults (28). Blood pressure in patients with end-stage renal diseases who are being treated by hemodialysis are also influenced by seasonal changes, with higher levels in summer and lower levels in the winter (2).

It has long been known that persons under thermal and physiological stress need to pay special attention to their fluid intake to prevent loss of water. The adverse consequence of inadequate water intake is dehydration; symptoms of acute dehydration vary from vague discomfort to death. Chronic or mild dehydration also accounts for various different morbidities and negative health consequences (22). An increased water intake has been shown to induce gallbladder emptying and it has been suggested that a high daily intake of water may prevent gallstone formation (24). As the gallbladder absorbs water passively, it is possible that dehydration contributes to the production of supersaturated bile, which subsequently becomes the major cause of gallstone formation. The easiest way to prevent dehydration is to encourage adequate water intake at all times during the warm summer months. It would be useful to conduct a prospective study to evaluate whether adequate hydration during the summer is able to prevent GSD-related cholecystitis.

Seasonal trends show that the monthly incidence of cholecystectomy is significantly reduced in February and then increases in March; furthermore, the incidence peaks in July, which is followed by significantly fall in August and then declined into winter. This pattern is likely to be due to cultural impacts and is particularly interesting. Most social events are synchronized by calendars in every cul-

ture. Traditional celebrations, gatherings and taboos are timed *via* the calendar, which in turn affects activities and behaviors of the people. Many residents in Southern China believe that there are wandering ghosts who are released from the underworld during the lunar month of July (ghost month, mostly August in the Gregorian calendar). People, therefore, avoid unnecessary risky activities during the ghost month, including elective surgery, outdoor activities and moving houses. A study in Taiwan has shown that the rate of elective caesarean section delivery decreases significantly during the ghost month in Taiwan (19). However, it has also been reported that the mean number of unintentional drowning deaths between 1981 and 2005 in Taiwan during ghost month is lower than during the non-ghost months (35). Although such beliefs are unscientific, irrational and a superstition, physicians usually respect these beliefs as they do affect decision-making and behavior. These cultural conditions may predispose Taiwanese to having the lowest incidence of cholecystectomy during February (around the Chinese New Year) and having a relatively low rate during August, the ghost month. These cultural beliefs may lead to surgeries being delayed resulting in an increased risk to patients delaying surgeries unnecessarily.

There are a number of limitations to our study. Firstly, it was impossible for us to obtain adequate information on religious beliefs or ecological myths that might help to identify more precisely the meteorological associations with cholecystectomy. Secondly, medical charts were unavailable to verify the true reasons for cholecystectomy; some operations might be performed at the time when they were urgently needed, while others might have been delayed cases. Despite these problems, our study has revealed that the overall incidence of cholecystectomy has increased steadily over the 13-year study period for all age groups and, in addition, the incidence of cholecystectomy is correlated with seasonal variations. Of these, temperature was found to be the most notable variable among the meteorological factors. However, cultural beliefs also seem to play a role in the observed correlations. Computational epidemiology and intelligent mining of datasets are essential tools that help increase the awareness of healthcare providers and individuals.

Acknowledgment

This study was supported by Cheng-Hsin General Hospital and National Yang-Ming University.

References

1. Afdhal, N.H., Chopra, S. and Travis, A. Epidemiology and risk

- factors for gallstone. Available at: <http://www.uptodate.com>. Assessed Date: March 15, 2010.
2. Argilés, A., Mourad, G. and Mion, C. Seasonal changes in blood pressure in patients with end-stage renal disease treated with hemodialysis. *N. Engl. J. Med.* 339: 1364-1370, 1998.
 3. Bartlett, A. and Parry, B. Cusum analysis of trends in operative selection and conversion rates for laparoscopic cholecystectomy. *ANZ J. Surg.* 71: 453-456, 2001.
 4. Budzyński, P., Pogoda, W. and Pogodziński, M. Seasonal variation and influence of atmospheric pressure diurnal fluctuations on occurrence of acute complications in patients with stomach and duodenal ulcer. *Przegl. Lek.* 57: 611-613, 2000.
 5. Chen, K.Y., Lou, H.Y., Lin, H.C. and Lee, S.H. Seasonal variation in the incidence of gastroesophageal reflux disease. *Am. J. Med. Sci.* 338: 453-458, 2009.
 6. Chen, S.F. Relationship between national peptic ulcer and seasonal variation. *Taipei City Med. J.* 5: 429-431, 2008.
 7. Chen, Y.K., Lin, H.C., Chen, C.S. and Yeh, S.D. Seasonal variations in urinary calculi attacks and their association with climate: a population based study. *J. Urol.* 179: 564-569, 2008.
 8. Fakheri, R.J. and Goldfarb, D.S. Ambient temperature as a contributor to kidney stone formation: implications of global warming. *Kidney Int.* 79: 1178-1185, 2011.
 9. Ginnett, D.A., Theis, J.H. and Kaneko, J.J. Spontaneous gallstone formation in deer mice: interaction of cholesterol, bile acids, and dietary fiber. *J. Wildl. Dis.* 39: 105-113, 2003.
 10. Hadley, C. and Patil, C.L. Seasonal changes in household food insecurity and symptoms of anxiety and depression. *Am. J. Phys. Anthropol.* 135: 225-232, 2008.
 11. Hajat, S., Kovats, R.S. and Lachowycz, K. Heat-related and cold-related deaths in England and Wales: who is at risk? *Occup. Environ. Med.* 64: 93-100, 2007.
 12. Hardy, K.J., Miller, H., Fletcher, D.R., Jones, R.M., Shulkes, A. and McNeil, J.J. An evaluation of laparoscopic versus open cholecystectomy. *Med. J. Aust.* 160: 58-62, 1994.
 13. Hashizume, M., Wagatsuma, Y., Hayashi, T., Saha, S.K., Sreatfield, K. and Yunus, M. The effect of temperature on mortality in rural Bangladesh—a population-based time-series study. *Int. J. Epidemiol.* 38: 1689-1697, 2009.
 14. Hollington, P., Toogood, G.J. and Padbury, R.T. A prospective randomized trial of day-stay only versus overnight-stay laparoscopic cholecystectomy. *Aust. N. Z. J. Surg.* 69: 841-843, 1999.
 15. Hosseini, S.V., Torabijahromi, M., Mosallaei, M., Sabet, B. and Pourahmad, S. The effect of season and Ramadan fasting on the onset of acute cholecystitis. *Saudi Med. J.* 27: 503-506, 2006.
 16. Kane, R.L., Lurie, N., Borbas, C., Morris, N., Flood, S., McLaughlin, B., Nemanich, G. and Schultz, A. The outcomes of elective laparoscopic and open cholecystectomies. *J. Am. Coll. Surg.* 180: 136-145, 1995.
 17. Kao, C.C., Huang, J.L., Ou, L.S. and See, L.C. The prevalence, severity and seasonal variations of asthma, rhinitis and eczema in Taiwanese schoolchildren. *Pediatr. Allergy Immunol.* 16: 408-415, 2005.
 18. Kuwabara, K., Matsuda, S., Ishikawa, K.B., Horiguchi, H. and Fujimori, K. Comparative quality of laparoscopic and open cholecystectomy in the elderly using propensity score matching analysis. *Gastroenterol. Res. Pract.* 2010: 490147, 2010.
 19. Lin, H.C., Xirasagar, S. and Tung, Y.C. Impact of a cultural belief about ghost month on delivery mode in Taiwan. *J. Epidemiol. Commun. Health* 60: 522-526, 2006.
 20. Lo, S.S., Johnston, R., Al Sameraai, A., Metcalf, P.A., Rice, M.L. and Masters, J.G. Seasonal variation in the acute presentation of urinary calculi over 8 years in Auckland, New Zealand. *BJU Int.* 106: 96-101, 2010.
 21. Lyass, S., Perry, Y., Venturero, M., Muggia-Sullam, M., Eid, A., Durst, A. and Reissman, P. Laparoscopic cholecystectomy: what does affect the outcome? A retrospective multifactorial regression analysis. *Surg. Endosc.* 14: 661-665, 2000.
 22. Manz, F. and Wentz, A. The importance of good hydration for the prevention of chronic diseases. *Nutr. Rev.* 63: S2-S5, 2005.
 23. Marschall, H.U. and Einarsson, C. Gallstone disease. *J. Intern. Med.* 261: 529-542, 2007.
 24. Math, M.V., Rampal, P.M., Faure, X.R. and Delmont, J.P. Gallbladder emptying after drinking water and its possible role in prevention of gallstone formation. *Singapore Med. J.* 27: 531-532, 1986.
 25. McMichael, A.J., Wilkinson, P., Kovats, R.S., Pattenden, S., Hajat, S., Armstrong, B., Vajanapoom, N., Niciu, E.M., Mahomed, H., Kingkeow, C., Kosnik, M., O'Neill, M.S., Romieu, I., Ramirez-Aguilar, M., Barreto, M.L., Gouveia, N. and Nikiforov, B. International study of temperature, heat and urban mortality: the 'ISOTHURM' project. *Int. J. Epidemiol.* 37: 1121-1131, 2008.
 26. Polychronidis, A., Botaitis, S., Tsaroucha, A., Tripsianis, G., Bounovas, A., Pitiakoudis, M. and Simopoulos, C. Laparoscopic cholecystectomy in elderly patients. *J. Gastrointest. Liver Dis.* 17: 309-313, 2008.
 27. Ramasubramanian, V. Time-series analysis, modeling and forecasting using SAS software. Available at: http://www.iasri.res.in/sscnars/sas_manual/5-ts_sas_lecture.pdf
 28. Semenza, J.C., McCullough, J.E., Flanders, W.D., McGeheh, M.A. and Lumpkin, J.R. Excess hospital admissions during the July 1995 heat wave in Chicago. *Am. J. Prev. Med.* 16: 269-277, 1999.
 29. Su, H.Y. and Lee, W.J. Laparoscopic cholecystectomy in older patients: clinical experience from 56 consecutive patients in a rural community hospital in Taiwan. *Surg. Laparosc. Endosc. Percutan. Tech.* 19: 227-230, 2009.
 30. Tsai, C.J. and Lin, C.Y. Seasonal changes in symptomatic duodenal ulcer activity in Taiwan: a comparison between subjects with and without haemorrhage. *J. Intern. Med.* 244: 405-410, 1998.
 31. Wang, J.K., Foster, S.M. and Wolff, B.G. Incidental gallstones. *Perm. J.* 13: 50-54, 2009.
 32. Wangdi, K., Singhasivanon, P., Silawan, T., Lawpoolsri, S., White, N.J. and Kaewkungwal, J. Development of temporal modelling for forecasting and prediction of malaria infections using time-series and ARIMAX analyses: a case study in endemic districts of Bhutan. *Malar. J.* 9: 251-260, 2010.
 33. Wen, C.P., Tsai, S.P. and Chung, W.S. A 10-year experience with universal health insurance in Taiwan: measuring changes in health and health disparity. *Ann. Intern. Med.* 148: 258-267, 2008.
 34. Xirasagar, S., Lin, H.C. and Chen, C.S. Role of meteorological factors in duodenal ulcer seasonality: a nation-wide, population-based study. *J. Gen. Intern. Med.* 22: 1439-1446, 2007.
 35. Yang, C.H., Huang, Y.T., Janes, C., Lin, K.C. and Lu, T.H. Belief in ghost month can help prevent drowning deaths: a natural experiment on the effects of cultural beliefs on risky behaviours. *Soc. Sci. Med.* 66: 1990-1998, 2008.