

# Time series analysis of poisonings treated in a hospital emergency department

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## CONFLICT OF INTEREST:

None

**Objective:** To establish a system of quality control for calculating the weekly cumulative incidence rates of poisonings treated in a hospital emergency department.

**Material and methods:** Daily reports of poisoning cases treated in the emergency department of Hospital NS Candelaria from January 2005 to December 2009 were used to provide the time series for analysis of weekly cumulative incidence rates. An autoregressive integrated moving average (ARIMA) model was used to predict the expected endemic rate, to provide sufficient warning to allow for preparation of appropriate interventions based on that indicator's behavior.

**Results:** A total of 3550 reports of poisoning were collected. The annual cumulative incidences for the period studied ranged from  $128 \times 10^5$  residents of the hospital's catchment area in 2005 to  $203 \times 10^5$  in 2009 (weekly increase of 0.6%). The ARIMA model fitted to the 2005-2008 subseries predicted the behavior of 2009 incidence rates, which adequately reflected observations for that year.

**Conclusions:** A comparison between the actual flow of poisoning cases in 2009 and the behavior of incidence rates predicted by the statistical model for that period suggests that this technique is a reliable and appropriate tool for monitoring the process of care in poisoning cases attended by a hospital emergency department wishing to bring intervention planning into line with expected incidence. [Emergencias 2011;23:193-199]

**Key words:** Poisoning. Emergency health services. Time series analysis. ARIMA model. Quality control.

## Introduction

Seeking medical attention at the emergency department (ED) within the health services has become a social habit of increasing and uncontrollable demand, which has forced us to modify and adapt the service offered. Hospital EDs' primary mission is to respond to urgent health problems of the population through effective efficient quality care<sup>1</sup>.

The WHO defines quality care as that which ensures that all patients receive the most complete diagnostic and therapeutic care to achieve the best possible result and maximum satisfaction with the least possible risk of iatrogenic harm<sup>2</sup>.

The ED has experienced rapid and profound changes in the last few decades, in response to

the rapid increase in demand for its services. It may be defined as an organization of health professionals located in the hospital which offers multidisciplinary attention, meeting functional, structural and organizational requirements to ensure safety, quality and effectiveness in treating accident and emergency victims<sup>3</sup>. At the same time, the ED is an intermediate unit, offering medical and nursing care to stabilize clinical patients who are ultimately admitted to the hospital, and a final unit for those who are treated and discharged home by the ED. In 2007, 26,265,096 visits (79.4% in public hospitals) were made to Spanish EDs, attending 585.3 per thousand population of whom 10.5% were admitted to hospital. The total number of hospital EDs increased by 23.2% between 2001 and 2007. ED attendance rate in

Spain is significantly higher than in the UK or USA, and the estimated rate of improper use varies between 24% and 79%<sup>3</sup>.

Frequent ED use means sporadic overcrowding which undermines the quality of care. If quality control measures are not introduced to identify potential causes of errors and, consequently, solutions and updated working methods, the quality of care tends to deteriorate. The problem of inappropriate ED use is common to many countries, and several studies have addressed this issue and examined the factors associated with misuse<sup>4-10</sup>. However, the wide range of criteria used to define such misuse has been an obstacle for systematic reviews on the subject.

A study by Ruger et al.<sup>11</sup> indicates that substance abuse is one of the most important contributing factors. Thus, as indicated by Burillo et al.<sup>12</sup>, acute poisoning is a classical clinical situation attended in Spanish EDs, unlike USA where most cases of poisoning are attended by telephone and recorded at Poison Control Centers<sup>13-16</sup>.

In recent years, indicators have emerged to measure quality of care for poisoned patients visiting the ED. Amigo et al.<sup>2</sup> developed a map of 25 quality indicators defining minimum standards for measuring quality of care in the ED of Hospital Clínic de Barcelona. Nogué et al.<sup>17</sup> proposed a map of 24 indicators for the same purpose. To achieve adequate quality of care we need to know the expected or predicted demand for attention which conditions decisions on planning and organizing hospital work. In the area of emergency cases of poisoning, this prediction is modeled on the most likely future demand for this type of care. The technique used to build such models is time series analysis, more commonly used in physics, demographics, economics and stock market analysis, but scarcely employed in emergency medicine. The aim of this study was to build a model that predicts weekly cumulative endemic rate of poisoning treated in the ED, carried out at the Hospital Universitario Nuestra Señora de la Candelaria (HUNSC), Tenerife.

## Method

This study was conducted in the emergency department of HUNSC which serves the municipalities in the northern area of Tenerife, as well as the islands of La Gomera and El Hierro, with a reference population of 411,394 inhabitants and an average 250,000 tourists per month.

This study used the diagnosis of poisoning as per the International Classification of Diseases, 10th edition (ICD-10), code numbers 15 (T36-T50, poisoning by medication) and 16 (T51-T65, poisoning by non-medical substances). The criteria for inclusion as a "case" in our study were (a) having taken at least one of the toxic substances included in this range and (b) visiting the ED for a related adverse reaction or event.

Data were taken from the ED electronic database recorded between 1 January 2005 and 31 December 2009. For each identified case we recorded the type of poisoning, age, sex, date and day of the week of ED care and destination. The research complied with the ethical standards of confidentiality. Based on the cases identified, we obtained a weekly cumulative series rate of poisoning treated in the ED, where the numerator was the number of cases per day of the week (from Monday at 0:01 am to Sunday at 12 pm) and the denominator was the population at risk, according to the census data 2005, published by the Institute of Statistics, Canary Islands, (ISTAC). Prognostic estimates were made by extrapolating, for the next years, the equation  $P^t = P_0 (1 + r)^t$ , where  $P$  = population according to the 2005 census,  $r$  = constant annual progression and  $t$  = time difference in years between 2005 and the year whose population size is being estimated.

Data analysis was performed using a description of the sample by type of poisoning, demographics, hospital department admission, and frequency of poisoning according to day of the week. Pearson's chi-square test was used to compare gender distribution. The time series of weekly cumulative incidence rates of poisoning treated in the period 2005 to 2009 were split into two sections, from 2005 to 2008, to derive the model, and 2009 to test the resulting predictions. Using spectral analysis techniques, regularities in the first series and ARIMA (autoregressive integrated moving average) time series models<sup>18</sup> were identified, adjusted, and tested to then select the most accurate prognostic model with the best fit, stability and parsimony. These models were then used to obtain the 2009 prediction and compared with the rate actually observed for that period. The calculations and graphs were obtained using the statistical package SPSS version 17.0 Co., Chicago, Ill., USA.

## Results

We obtained a total sample of 3,550 cases of

**Table 1.** Distribution of poisoning by sex, age and time period studied

Characteristics	Period					
	2005-2009	2005	2006	2007	2008	2009
Sex (Male / Female) <sup>a</sup>	1,938/1,502 (56/44)	284/260 (52/48)	298/240 (55/45)	509/323 (61/39)	473/337 (58/42)	383/342 (53/47)
p value <sup>b</sup>	< 0.001	0.07	< 0.05	< 0.001	< 0.001	0.06
Age (years) <sup>c</sup>	34 (1-101)	20 (5-101)	49 (5-97)	38 (3-96)	29 (2-101)	22 (1-99)

<sup>a</sup>Absolute frequency (relative frequency). <sup>b</sup>According to Pearson's Chi-square test. <sup>c</sup>Median (range).

poisoning attended during the the 5-year study period. The distribution by sex and age are shown in Table 1. A higher frequency of poisoning was found in men ( $p < 0.001$ ). Median age was 34 years (range 1 – 101 years). The frequency of poisoning according to day of the week is depicted in Figure 1, showing the highest rates at the end of the week (46.9%).

The main types of poisoning are described in Table 2. The most frequent were those associated with medication (40%), followed by alcohol abuse (31.3%). Only 5.3% of all patients required hospital admission, mostly to the intensive care unit (40%) and department of internal medicine (25.3%) as shown in Table 3.

Figure 2 depicts the cumulative weekly incidence of poisoning from 2005 to 2009. It shows non-random behavior of the variable with an increasing trend and a short period of suspected oscillation. The statistical test of runs indicated that the sequence was not random. The trend was fitted to linear, quadratic, exponential, S-curve and moving average models; the linear model yielded the lowest mean squared error (1.19) and mean absolute error (0.87), so it was selected as the most appropriate for the trend. The trend model was  $t = 2.4 + (0.006 \times \text{week})$ , which indicated a weekly increase in poisoning of 0.6%.

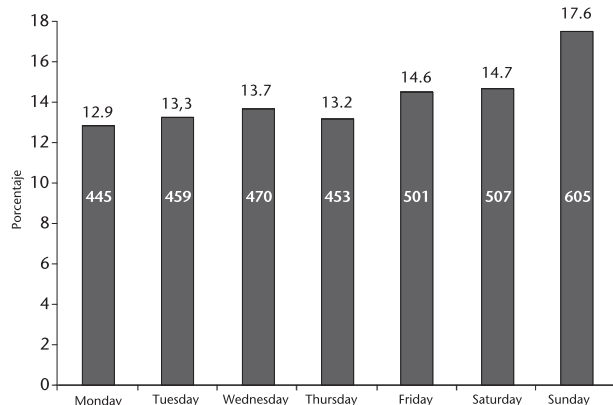
The linear trend model was fitted to the 2005-2008 time series and residues were obtained. We constructed simple and partial correlograms for 70 time lags and the periodogram of these residuals, whose configurations pointed to consistent auto-correlations up to lag 4 and periodic oscillation of 12 weeks. This pattern is standard for an ARIMA (1,0,1) x SARIMA12 (1,0,0) model, from which the most appropriate ARMA model (1.1) was derived, with a constant set by backward steps<sup>18</sup>. Exploration of the residuals left by this model made up white noise. The model presented stable coefficients. It was used to predict weekly cumulative incidence of poisoning for 2009 with a random fluctuation threshold of 95%, which was then compared with the observed rate; the results are presented in Figure 3.

## Discussion

The gender distribution of poisoning in our study showed a predominance of men in all the years studied, with significant differences in the overall period 2005-2009 and for the years 2006, 2007 and 2008. This male predominance is consistent with data published by various authors<sup>12,19,20</sup> and the Hispatox study<sup>21</sup> which included thirty four 2nd and 3rd level Spanish hospitals belonging to all Spanish regions. Other authors have reported higher rates of women than men attended in the ED for poisoning<sup>2,17</sup>.

The median age in our sample was 34 years. Burillo et al.<sup>12</sup> reported 33 years as the average age of ED patients attended for poisoning in their study, similar to Pastó et al.<sup>22</sup>, Amigo et al.<sup>2</sup> and the Hispatox study<sup>21</sup> which included 2981 people attended and an average age of 35.7 years. In the studies by Gonzalez-Fernandez and Alonso-Fernández<sup>20</sup> and Nogué<sup>23</sup>, the average age of was 42 years and  $41.6 \pm 15$  years respectively.

A greater proportion of poisonings by day of the week corresponded to those at the end of the week, attended Friday through Sunday and representing 46.9% of the total. These results are consistent with most other studies<sup>12,19-21</sup>.



**Figure 1.** Frequency of poisoning by day of the week. Within each bar is the sum of poisoning cases attended that day of the week in the period from 2005 to 2009. Above each bar is the percentage of cases attended that day for the whole period from 2005 to 2009.

**Table 2.** Type of poisoning by study time period

Type of poisoning	Period					
	2005-2009 n (%)	2005 n (%)	2006 n (%)	2007 n (%)	2008 n (%)	2009 n (%)
Medicinal drugs	1,421 (40.0)	213 (39.2)	237 (43.7)	233 (28.2)	405 (44.6)	333 (45.6)
Alcohol	1,112 (31.5)	184 (33.9)	182 (33.6)	243 (29.4)	258 (28.4)	245 (33.5)
Other drugs	311 (8.7)	15 (2.7)	26 (4.7)	156 (18.8)	89 (9.8)	25 (3.4)
Food	157 (4.4)	37 (6.8)	27 (4.9)	45 (5.4)	24 (2.6)	24 (3.3)
Autolysis	86 (2.0)	7 (1.3)	7 (1.3)	30 (3.6)	26 (2.9)	16 (2.2)
Organophosphates	66 (1.8)	15 (2.7)	10 (1.8)	21 (2.5)	12 (1.3)	8 (1.1)
Gas	49 (1.4)	10 (1.8)	3 (0.6)	13 (1.6)	12 (1.3)	11 (1.5)
Sodium hydroxide	43 (1.2)	7 (1.3)	4 (0.7)	13 (1.6)	11 (1.2)	8 (1.1)
Other chemicals	29 (0.8)	6 (1.1)	1 (0.2)	6 (0.7)	7 (0.8)	9 (1.2)
Nonspecific	276 (7.8)	49 (9.0)	45 (8.3)	66 (7.9)	64 (7.0)	52 (7.1)
<b>Total</b>	<b>3,550 (100.0)</b>	<b>543 (100.0)</b>	<b>542 (100.0)</b>	<b>826 (100.0)</b>	<b>908 (100.0)</b>	<b>731 (100.0)</b>

Regarding the type of poisoning attended, pharmaceutical drugs predominated in all five years of the study, with an average 40% for the whole study period. Pastó et al.<sup>23</sup> studied poisoning treated in a hospital ED during two periods, 1994 and 2004 and found that the prevalence of pharmaceutical drug poisoning was 51.3% and 62.7%, respectively. Other studies also indicate pharmaceutical drugs as one of the leading causes of poisoning treated in the ED<sup>2,21</sup>.

In our study, alcohol was the second most frequent cause of poisoning, accounting for 31.3% of the total. Carpintero et al.<sup>19</sup> in a hospital ED study in La Rioja reported that the leading cause of poisoning was alcohol abuse (34.8%). Consumption of alcohol in Spain is mainly associated with weekends. With respect to the consequences of alcohol abuse, these have changed in recent years: chronic conditions such as cirrhosis have decreased while alcohol-related traffic accidents have increased, along with alcohol poisoning<sup>24</sup>. Most studies point to alcohol abuse as one of the main causes of poisoning, especially among the young and during weekends<sup>2,12,19,20,23</sup>.

Other drugs involved in poisoning included cocaine, designer drugs, heroin, etc., accounting for 8.8% of all poisonings treated in the ED. In other

studies, the consumption of these drugs is a major cause of poisoning treated in the ED<sup>2,21,23</sup>. Suicide attempts were identified as the reason for poisoning treated in our ED, accounting for 2.4% of the cases, which was lower than the rates reported elsewhere<sup>2,20,23</sup>.

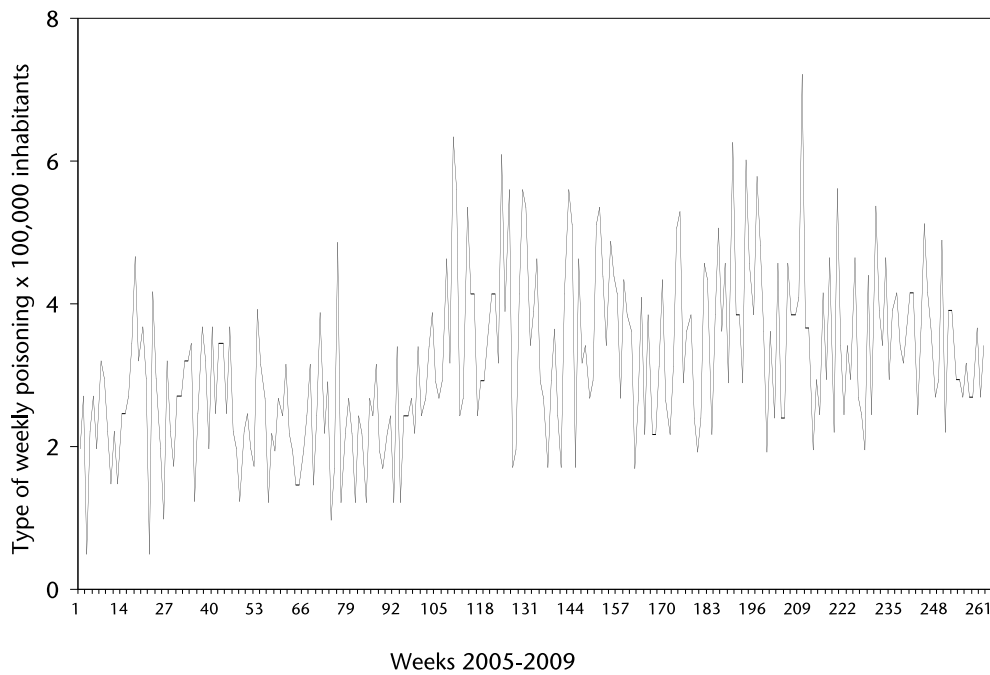
In our study 5.4% of patients were admitted to hospital, with 2.1% being transferred to the intensive care unit (ICU) (2.1%) and 3.2% to other departments. By way of comparison, González-Fernández and Alonso-Fernández<sup>20</sup> reported rates of 2% ICU admission and 2% other departments.

The predictive model on the weekly cumulative rate of poisoning attended in the ED seemed adequate, judging from goodness of fit, the results of residual analysis and comparison with observed data. The indicator remained within its range of random fluctuation, which varied around the expected value, with no abnormalities in behavior, and adequately captured the decline in 2009 despite the rising trend during 2005 to 2008.

Trends, cycles, seasonal movements, weekly oscillations and other regular patterns of demand for poisoning treatment in the ED are important to identify and predict. Having such an indicator of expected demand in the ED allows planning the resources required to meet such demand. An-

**Table 3.** Destination of poisoned patients requiring hospitalization by study time period

Hospital department	Period					
	2005-2009 n (%)	2005 n (%)	2006 n (%)	2007 n (%)	2008 n (%)	2009 n (%)
Intensive Care Unit	76 (40.0)	15 (35.7)	9 (40.9)	28 (49.1)	13 (32.5)	11 (37.9)
Internal Medicine	49 (25.3)	6 (14.3)	4 (18.2)	16 (28.1)	12 (30.0)	11 (37.9)
Pediatrics	28 (14.7)	7 (16.7)	5 (22.7)	7 (12.3)	6 (15.1)	3 (10.3)
Coronary Unit	22 (11.5)	10 (23.8)	3 (13.6)	3 (5.3)	3 (7.5)	3 (10.3)
Cardiology	4 (2.1)	1 (2.4)	1 (4.5)	1 (1.8)	0 (0.0)	1 (3.4)
Gastrointestinal	4 (2.1)	1 (2.4)	0 (0.0)	1 (1.8)	2 (5.0)	0 (0.0)
Gynecology	4 (2.1)	2 (4.8)	0 (0.0)	0 (0.0)	1 (2.5)	0 (0.0)
Neurology	2 (1.0)	0 (0.0)	0 (0.0)	1 (1.8)	2 (5.0)	0 (0.0)
Neonatal	1 (0.5)	0 (0.0)	0 (0.0)	0 (0.0)	1 (2.5)	0 (0.0)
<b>Total</b>	<b>190 (100)</b>	<b>42 (100)</b>	<b>22 (100)</b>	<b>57 (100)</b>	<b>40 (100)</b>	<b>29 (100)</b>

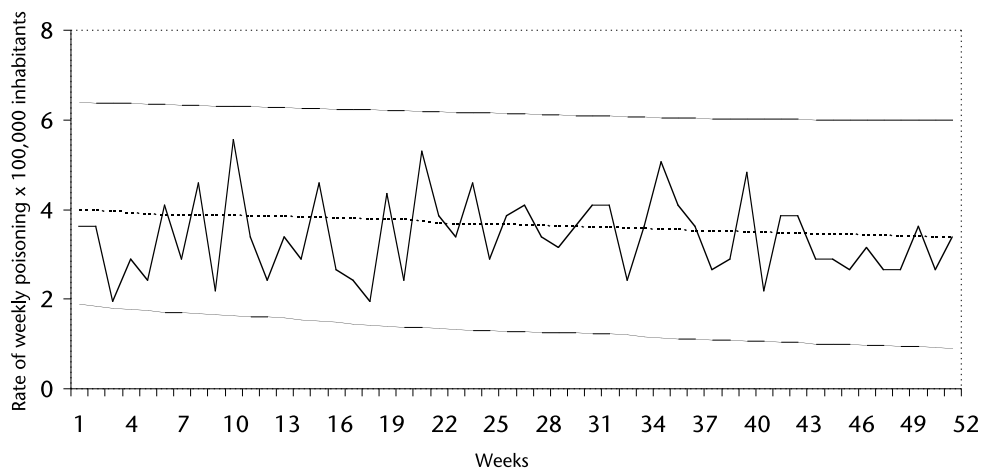


**Figure 2.** Weekly cumulative incidence rate of ED-attended poisoning treated in the period 2005 to 2009.

other practical use of this is to monitor and detect unusual patterns of demand. The most significant is a sustained increase of the indicator above its threshold of expected fluctuation according to chance, which acts as a warning signal to identify possible causes and areas for improvement in the organization of the ED for optimal care. In this analysis we must consider that an increase in the number of cases may be influenced by increased accessibility and possibility of care. In studies specifically designed to identify factors that could

reduce the incidence of some avoidable cases of poisoning, these predictive models also represent a useful tool. And the impact of interventions on the problem can also be assessed by comparing the expected incidence with data observed after such intervention.

This study has certain limitations, including patient selection bias: our patients were from a particular geographical area, with the characteristics of a specific population and the ED, so these results may not be extrapolated to other situations.



**Figure 3.** Comparison between observed and predicted weekly incidence rate of poisoning in 2009, attended by the Emergency Department, Hospital Universitario Nuestra Señora de la Candelaria, and fluctuation threshold with 95% confidence interval.

However, the study shows the usefulness of a predictive model of poisoning attended in the ED, and in this sense it is applicable to any ED and population. A limitation to the use of such predictive models is that they remain valid only as long as there are no changes in the characteristics of ED organization and operation, and the mechanism of identification and registration of cases.

In conclusion we propose that a predictive model of poisoning requiring urgent attention is a useful tool for quality management of the hospital ED, since it allows appropriate planning of resources necessary for proper attention, and assessment of the impact of preventive interventions on this health problem.

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## **Análisis de series temporales aplicado a intoxicaciones atendidas en urgencias hospitalarias**

**García Andrés MC, Arias Rodríguez A, Rodríguez Álvarez C, Morcillo Rehberger A, Aguirre-Jaime J**

**Objetivo:** Establecer un sistema de control de calidad estadística para la tasa de incidencia acumulada semanal de intoxicaciones atendidas en un servicio de urgencias hospitalario.

**Métodos:** Se empleó las notificaciones diarias de casos atendidos por intoxicaciones en el servicio de urgencias del Hospital Nuestra Señora de la Candelaria, entre enero de 2005 y diciembre de 2009 para conformar la serie temporal de tasas las semanales de incidencia acumulada. Mediante metodología ARIMA (modelos autorregresivos integrados de medias móviles) se predijo el valor endémico esperado de esta tasa con un periodo de antelación suficiente como para tomar medidas de intervención oportunas a partir del comportamiento observado en este indicador.

**Resultados:** Se recopiló una muestra de 3.550 notificaciones de intoxicaciones atendidas. Las tasas de incidencia acumulada anual en el periodo estudiado fluctuaron entre 128 por 100.000 habitantes del área de influencia del hospital en 2005 y 203 x por 100.000 en 2009, con un incremento semanal del 0,6%. El modelo ARIMA ajustado a la subserie 2005-2008 produjo un pronóstico de comportamiento de la tasa de intoxicaciones para 2009 que contrastado con lo observado en ese año nos permitió considerarlo adecuado.

**Conclusiones:** El contraste del canal de control de calidad estadística de las intoxicaciones atendidas en urgencias con esta técnica para 2009 con el comportamiento observado en ese indicador durante ese mismo año permite considerar a este instrumento como adecuado y fiable para monitorizar el proceso asistencial de atención a las intoxicaciones en el servicio de urgencias hospitalario con vistas a una intervención oportuna sobre su incidencia. [Emergencias 2011;23:193-199]

**Palabras clave:** Intoxicaciones. Urgencias hospitalarias. Series temporales. Modelo ARIMA. Control de calidad.