ORIGINAL ARTICLE

Potential capacity of an emergency dispatch center to predict COVID-19–related hospital and intensive care unit admissions

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Objective. To analyze the association between the perceived care demand in the emergency call center of Castilla La Mancha (and hospital and ICU admissions for COVID-19, as well as their temporal characteristics, to explore its potential capacity as a predictive tool for COVID hospital admissions.

Methodology. Retrospective observational study on the daily calls made to the emergency call center of Castilla La Mancha, both calls to 112 and those made to COVID line, in the period between March 1 and October 14, 2020. The data were analyzed by codes "diarrhea", "dyspnea", "fever" and "general discomfort" that were used as predictor variables, and their relationship with hospital admissions and ICU admissions.

Results. A total of 831,943 calls were received at the CLM emergency call center through 112, with a maximum on March 13, 2020 with 10,582 calls. On COVID line, a total of 208,803 calls were received in that period, with a maximum on March 15 with 23,744. A statistically significant relationship was found between the regulation codes studied (specific symptoms) and the number of calls with hospital admissions and ICU admissions, with a predictive capacity of 2 weeks in relation to occupancy peaks. The codes with the greatest relationship were "general malaise" and "diarrhea".

Conclusion. We have found an association between the number of calls to a CCUE due to dyspnea, fever, general discomfort, diarrhea and the number of calls with hospital admissions and ICU for COVID-SARS-2 2 weeks in advance, mainly due to general discomfort and diarrhea. The design of predictive expert systems and their automation using artificial intelligence could be part of the preparation, planning and anticipation programs of health systems in the near future in the event of future pandemics..

Keywords: Emergency dispatch center. COVID-19. Epidemiologic monitoring. Trends. Prediction.

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Contribution of the authors:
All authors have confirmed their authorship in the document of author responsibilities, publication agreement and assignment of rights to EMERGENCIAS.

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Information about the article:
Received: 24-3-2021
Accepted: 28-4-2021
Online: 7-9-2021

Editor in charge:
Agustín Julián-Jiménez

Capacidad potencial de un centro coordinador de urgencias y emergencias para predecir ingresos hospitalarios y en unidades de cuidados intensivos por COVID-19

Objetivo. Analizar la asociación entre la demanda asistencial percibida en el Centro Coordinador de Urgencias y Emergencias (CCUE) de Castilla La Mancha (CLM) y los ingresos hospitalarios y en unidades de cuidados intensivos (UCI) por COVID-19, así como sus características temporales, para valorar la potencial aplicación como herramienta predictiva de ingresos por COVID-19.

Método. Estudio observacional retrospectivo de las llamadas diarias realizadas al CCUE de CLM entre el 1 de marzo y el 14 de octubre de 2020. Se analizaron los códigos "diarrea", "disnea", "fiebre" y "malestar general" que fueron usados como variables predictoras, y su relación con los ingresos hospitalarios y en UCI.

Resultados. A través del 112 se recibieron 831.943 llamadas (máximo el 13 de marzo: 10.582 llamadas). En la línea 900 fueron 208.803 llamadas (máximo el 15 de marzo: 23.744 llamadas). Se encontró una relación estadísticamente significativa entre los códigos de regulación estudiados y el número de llamadas con los ingresos hospitalarios y en UCI, con una capacidad predictora de 2 semanas en relación a los picos de ocupación. Los códigos con mayor relación fueron "malestar general" y "diarrea".

Conclusiones. Se encontró una asociación entre el número de llamadas a un CCUE por disnea, fiebre, malestar general y diarrea y el número de llamadas con los ingresos hospitalarios y en UCI por COVID-19 con una antelación de 2 semanas, principalmente por malestar general y diarrea. El diseño de sistemas expertos predictivos y su automatización mediante inteligencia artificial podría formar parte de los programas de preparación, planificación y anticipación de los sistemas de salud ante futuras pandemias.

Palabras clave: Centro coordinador de urgencias. COVID-19. Vigilancia epidemiológica. Tendencias. Predicciones.

Introduction

The epidemiological surveillance system for communicable diseases in Spain, formed by the National Epidemiological Surveillance Network created by RD 2210/1995, is a model based fundamentally on the notification of compulsory reportable diseases by the sentinel physician system and the microbiological surveil-

lance networks. The current COVID-19 pandemic has caused controversies regarding early detection by traditional epidemiological surveillance systems and the establishment of preparedness measures and evaluation of the health system's response[1,2].

In Spain, the transfer of health care to the autonomous communities, together with the Decision of the Council of Europe 91/396 of 29 June 1991[3] to establish 112 as the single European emergency number, promoted the creation of the autonomous Emergency Medical Services (EMS) and their corresponding Emergency Coordination Centers (ECC) as a link between the different levels of care of the National Health System. There are still two main entry points for requests to the EMS (061 and 112), although the predominant model, according to the Council Decision of 29 July on the creation of a single European emergency call number (Official Journal No. L 217 of 06/08/1991 p. 0031 - 0032. 91/396/EEC), is the integrated model through 112. EMS has been an important gateway to the healthcare system for citizens in the current pandemic[4], which has affected its activity and daily operation as well as that of the rest of the healthcare system[5].

The ECCs receive emergency telephone calls for assistance from the population as well as handling a large amount of relevant data on a daily basis. These include data related to the signs and symptoms caused by the COVID-19 pandemic in the population demanding assistance[6,7]. Some countries monitor this information to create epidemiological alerts[8] using and analyzing these large data sets[9] even in real time[10]. Previous experiences in Spain have shown that it is possible to detect the peak of the seasonal influenza epidemic wave early using this type of system as a complementary method to traditional epidemiological surveillance[11], and there are already practical experiences in this regard[12]. The relevance of the ECC as a gateway to the health care system in pandemics and as a triage element has already been demonstrated[13]. From the beginning of the COVID-19 pandemic, the 112/061 telephone number was responsible for receiving all health demands, both urgent and for information, a fact that produced an overload of care that could have delayed the usual emergency and urgent care. For this reason, parallel flows were created using new telephone numbers for specific information requests by COVID-19 and maintaining 112/061 for urgent and emergent calls. These health information numbers have also proved useful in epidemiological surveillance[14].

Experience exists in the general use of real-time predictive systems for epidemic trends[15] and, in the case of COVID-19, of artificial intelligence and geographic information systems in predictive analysis to improve the preparedness and response of the health system to the pandemic[16]. Studies have also shown the usefulness of data generated in a ECC as a complementary tool to traditional epidemiological surveillance systems[17] and automatic predictive epidemiological surveillance systems[18,19]. In the COVID-19 pandemic, there are articles that relate calls to the emergency system and epidemiological surveillance[20], although they only analyze the trend of total calls and not specific types of calls. The current COVID-19 pandemic has boosted the study of health trend analysis. From the fields of mathematics and machine learning, complex mathematical models are being developed to try to predict the behavior of the COVID-19 epidemic wave[21]. In addition, different approaches are being explored to predict the need for conventional hospitalization and the use of intensive care units (ICUs) far enough in advance to allow adequate planning of healthcare resources[22]. In France, a web form was developed for the population to self-triage for COVID-19 symptoms in order to reduce telephone pressure on ECCs. In a subsequent analysis, it was found that the peak of completed questionnaires preceded the peak of patients hospitalized for COVID-19 by 5 days[23]. In Italy, complex mathematical models have been developed that predict ICU occupancy 3 days in advance[24] and the possibility of using data from social networks and internet searches to try to predict the epidemic wave has been explored[25]. The relationship between the number of daily positives and the increase in ICU hospitalizations after a few days is better known[26]. However, despite being widely implemented in our countries, we have not found any article analyzing the relationship between different health regulation codes in the ECC and hospital occupancy on ward or in the ICU.

Based on the hypothesis that there are indicator variables associated with calls to a ECCs that can potentially predict hospital and ICU admissions for COVID-19, the aim of this study is to analyze the association between the perceived demand for care in the ECC of Castilla La Mancha (CLM) and hospital and ICU admissions for COVID-19, as well as its temporal characteristics, to assess its potential application as a predictive tool for COVID-19 admissions.

Method

Retrospective descriptive observational study elaborated on the daily calls made to the ECC of CLM, both calls to 112 and those made to the 900 line, in the period between March 1 and October 14, 2020. CLM, according to INE 2020 data, has a population of 2,044,408 inhabitants, distributed in the 5 provinces (Albacete, Ciudad Real, Cuenca, Guadalajara and Toledo), with a geographical extension of 79,463 km^2 and a population density of 26.16 inhabitants per km^2. Geographical extension and population density are important elements for the design and sizing of an EMS. In CLM the gateway for any emergency is 112, where all agencies are integrated and where the health sector is also integrated in the same room. The ECC is located in Toledo, and from there all emergencies are managed and coordinated. During the COVID-19 pandemic, the gateway to the 112 service was duplicated with two 900 lines, one for consultancy and the other for symp-

Table 1. Total calls and calls received by regulatory codes

	Total	Mean	Median	(MD)	Interquartile range	95% CI	Maximum (Date)
Calls for diarrhea	2,759	12.9	11.5	(4.6)	5.75	(11.92-13.83)	51 (17-03-20)
Calls for dyspnea	3,936	18.4	14.5	(8.4)	7	(16.13-20.65)	166 (13-03-20)
Calls for fever	2,880	13.4	10	(7.4)	6	(11.52-15.38)	139 (12-03-20)
Calls for general malaise	13 883	64.8	59	(13.5)	16	(62.28-67.46)	145 (13-03-20)
112 calls	831 943	3,887.6	3,771	(503.3)	699.5	(3,782.80-3,992.36)	10,582 (13-03-20)
900 calls	208 803	975.7	374.5	(1,042.6)	538.5	(660.78-1,290.64)	18,155 (15-03-20)
Total calls	**1,040 746**	**4,863.3**	**4,222.5**	**(1,360.0)**	**813**	**(4,476.96-5,249.63)**	**23,744 (15-03-20)**

toms. In 112, there are demand operators and multisector response operators (they manage and coordinate the necessary public agencies in each incident), in addition to a 112-department chief. In the health sector, there are medical staff (one of them is the shift manager), nursing staff, meteorologist and health response managers.

The calls were coded according to the main sign or symptom manifested by the caller and thus collected by the healthcare coordinator according to the regulatory codes under study ("diarrhea", "dyspnea", "fever" and "malaise") which were used as predictor variables and which correspond to the regulatory codes used in the ECC with a greater similarity to the COVID-19 associated symptoms. In addition, data on total admissions and ICU admissions in CLM hospitals for the same time period were obtained and analyzed and used as outcome variables.

In the statistical analysis, the normality of the variable distributions was first checked by means of the skewness and kurtosis coefficients and the Lilliefors test, and expressed as mean and mean deviation (MD). The relationships between variables were studied by correlation and regression analysis and, in a second phase, by multiple regression for better subsets of predictor variables. A period of 2 weeks was considered as the time difference between the peaks of the dependent and independent variables. Confidence intervals (CI) of 95% were used.

Approval was obtained from the Research Ethics Committee of the Principality of Asturias (CEImPA Code no. 2021.214).

Results

Between March 1 and September 30, a total of 831,943 calls were received at the CLM ECC through the 112 line, with a daily average of 4,863 calls (SD: 2,867; 95% CI: 4,476-5,249) and a maximum of 10,582 calls on March 13, 2020. In addition, a total of 208,803 calls were received on the 900 line during this period, with a daily average of 976 calls (MD: 2,337; 95% CI: 661-1,290) and a peak on March 15 with 23,744. These data, together with those corresponding to coded calls (diarrhea, dyspnea, fever and general malaise), are shown in Table 1.

The day with the highest number of patients admitted to CLM hospitals for COVID was April 1 with 3,230 patients, and the maximum number of patients admitted to ICUs was reached on April 4 and 7 with 360 patients. Figure 1 shows the daily temporal distribution of the variables studied in the two peaks of the pandemic.

All the predictor variables studied showed significant correlations with hospital admissions and ICU admissions, being higher in the case of total admissions (Table 2). The three variables with the highest direct correlations were malaise, diarrhea and dyspnea. Weaker correlations were found with fever and with the number of calls, both total and to the 112 or 900 line. Figure 2 shows the correlation analysis between the dependent and independent variables with the highest significant correlation, together with their corresponding regression lines and their 95% CIs. In the analysis by best subsets of predictor variables for hospital admission and ICU admission, diarrhea and malaise appear to have been the main contributors to the joint predictive value ($p < 0.01$ and $p = 0.01$ for diarrhea and malaise and hospital admission, respectively, and $p < 0.01$ and $p = 0.01$ for diarrhea and malaise and hospital and ICU admission, respectively).

Discussion

In our study, calls to 112 and to the 900 line showed a low, although significant, correlation with hospital and ICU admissions in the following 2 weeks. The fact that no statistical significance was found in the linear regression analysis for calls to 112 and 900 reinforces the idea that coding for symptoms in a ECC is the main factor that could potentially be used as a predictive tool for COVID-19 admissions. The total number of calls could be influenced by previous information campaigns on the establishment of new telephone information lines and, therefore, the observed association may not be relevant in predicting trends despite the statistically significant association. Nevertheless, our results are comparable to other studies in which the number of calls to the ECC anticipated the peak of ICU admissions by more than 14 days[27]. In this study we are referring to, calls were not disaggregated by regulatory codes, but other aspects such as ambulance use were included.

Regarding the specific regulatory codes, we found a much stronger association with hospital and ICU admissions. After identifying the CLM ECC regulation codes best identified with the symptomatology of COVID-19[28], the correlation observed was significant between calls for general malaise and diarrhea and hospital admis-

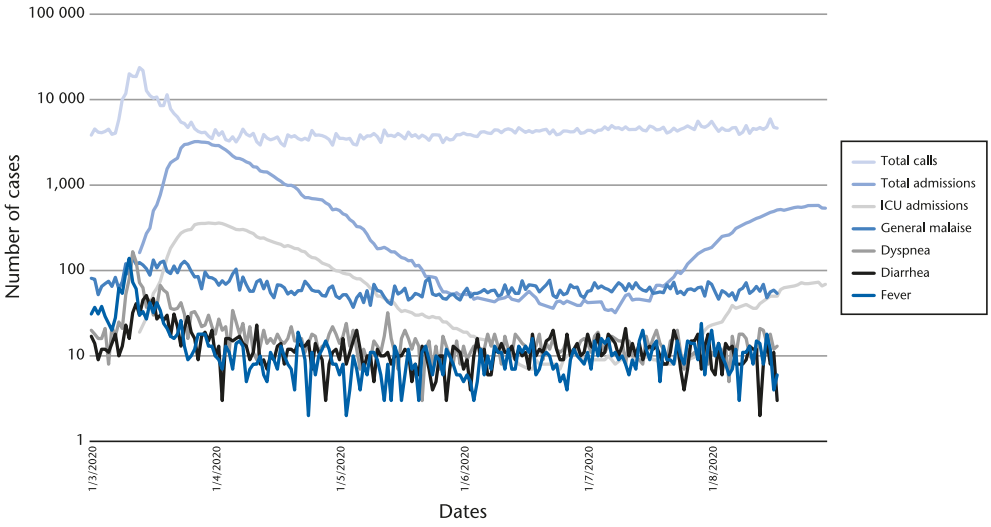

Figure 1. Temporal distribution of the variables studied (logarithmic frequency scale). ICU: intensive care unit.

sions, both in ICU and total admissions, as well as in the linear regression analysis. It was not possible to study the correlation with calls for cough because of the lack of specific coding. In the case of fever, despite being a typical symptom by COVID-19, the correlation was weak. We are unable to demonstrate a direct relationship between these symptoms and microbiological confirmation of COVID-19, but apart from the COVID-19 symptom frequency studies in which fever, cough, fatigue and dyspnea are identified as the most frequent symptoms[29], other more nonspecific symptoms perceived and manifested as such by the general population should probably be considered. These two symptoms (malaise and diarrhea) also obtain the best results in the best subset analysis as predictor variables. Probably the calls for malaise could be related to fatigue and dyspnea by the patient. Diarrhea can be considered as a well-defined symptom identified by the patient and the call operator. Therefore, its significant relationship with hospital admissions is striking despite being a symptom that, although described, is infrequent by COVID-19. The methodology employed in our study and the data sources used do not provide us with objective elements that would allow us to explain the possible causes of this result.

Although significant positive correlations were found with the total number of calls and calls to 112 and the 900 line, these are lower than in the symptom-based analysis. Still, this suggests that even ECCs that do not code calls could use the total number of calls to estimate the increase in hospital and ICU occupancy 2 weeks in advance of the pandemic. Obtaining higher statistical power in the case of specific symptoms highlights the importance of correct coding of calls to an ECC. A recent study has also confirmed this finding, although without establishing its relationship with indicators of hospital use[30]. The fact that ECCs are health system structures present in a large number of countries means that, through the implementation of appropriate data management, they can play an important role in the real-time epidemiological surveillance of the pandemic of COVID-19 and enhance their capacity as a tool for predicting hospital occupancy.

Among the limitations of our study is the confusion factor that the existence of 2 telephone numbers could have caused in the population, which could have produced a shift in the type of call between both lines. Even so, the strong implantation of 112 as the emergency number in CLM means that the data obtained from the calls due to symptoms perceived by the population are sufficiently reliable for the statistical results to have clinical relevance in the study universe. Another limitation inherent to the studies carried out in the ECCs is the possible variability between different ob-

Table 2. Correlation and multivariate linear regression analysis values

	Admissions ICU			Total admissions		
	r (p)	Multivariate regression coefficient	t (p)	r (p)	Multivariate regression coefficient	t (p)
Diarrhea	0.64 (< 0.001)	2.20	2.42 (0.016)	0.73 (< 0.001)	22.57	3.53 (< 0.001)
Dyspnea	0.60 (< 0.001)	1.37	2.93 (0.003)	0.70 (< 0.001)	6.35	1.91 (0.056)
General malaise	0.79 (< 0.001)	3.25	9.21 (0.000)	0.83 (< 0.001)	22.32	8.95 (< 0.001)
Fever	0.41 (< 0.001)	–0.057	–0.13 (0.89)	0.52 (< 0.001)	1.04	0.35 (0.726)
Call 112	0.31 (< 0.001)	–0.07	–2.40 (0.99)	0.48 (< 0.001)	–0.46	–0.00 (0.999)
900 calls	0.55 (< 0.001)	–0.02	–0.00 (1)	0.69 (< 0.001)	–0.23	–0.00 (1)
Total calls	**0.53 (< 0.001)**	**0.027**	**0.00 (1)**	**0.69 (< 0.001)**	**0.30**	**0.00 (0.999)**

r: correlation coefficient; ICU: intensive care unit.

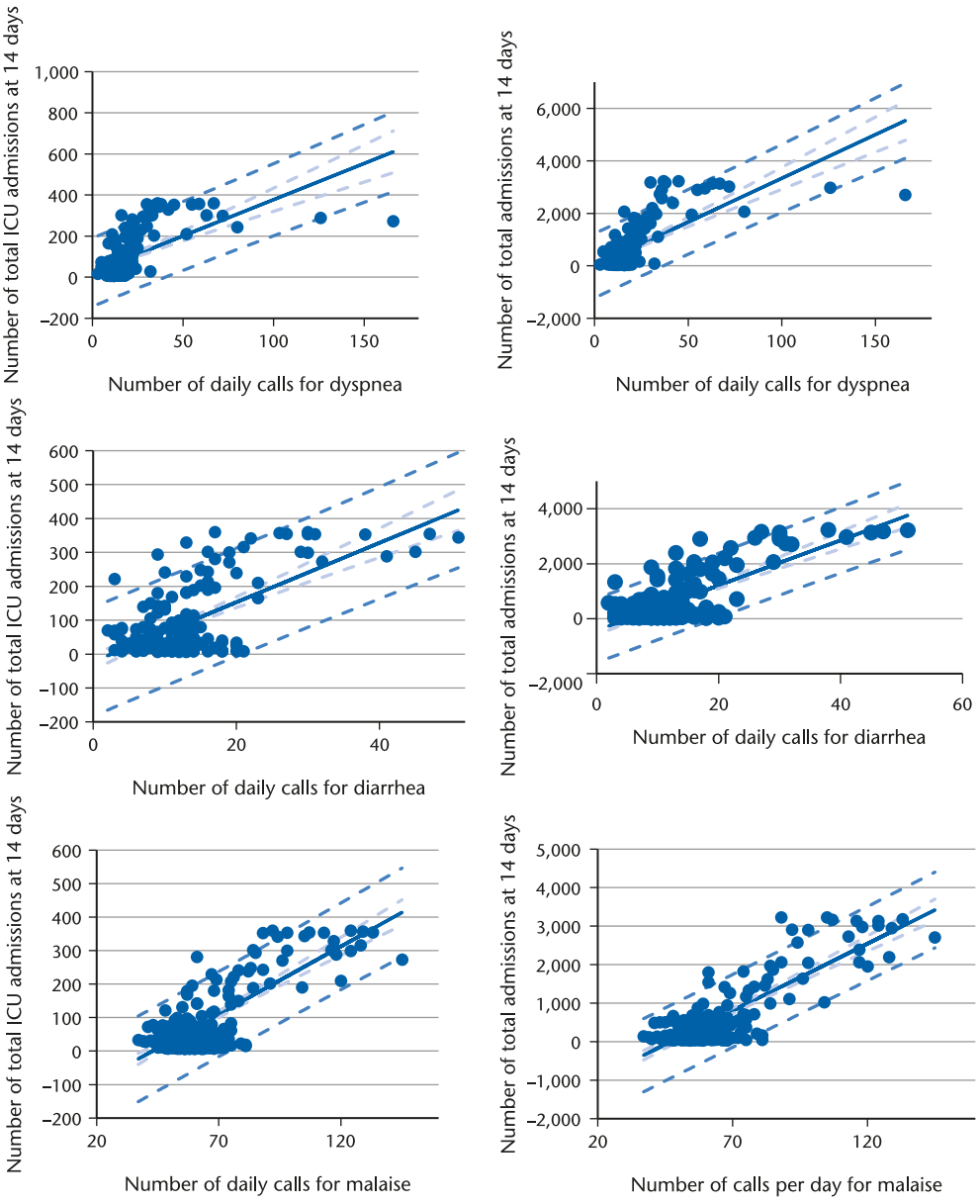

Figure 2. Plots of points and regression lines and their 95% confidence intervals for the prediction of the points (dark blue) and the regression line (light blue).

servers, in this case emergency operators. For this reason, it is necessary that the data collection architecture in the ECCs be carried out with the appropriate epidemiological approach for their adequate exploitation and use as predictive tools. The results of our study may not be extrapolated to other ECCs or geographical areas, which would require a different epidemiological approach and design. In this sense, an adequate architecture in the call classification system is key, which would be desirable to have a structure based on epidemiological data collection models.

In conclusion, an association was found between the number of calls to a ECC for dyspnea, fever, malaise, diarrhea, and number of calls with hospital and ICU admissions for COVID-19 with a 2-week anticipation, primarily calls for malaise and diarrhea. Correct coding of calls to the ECC, together with the design of predictive expert systems and their automation using artificial intelligence could in the near future form part of the preparedness, planning and anticipation programs of health systems in the face of future pandemics.

Conflicting interests: The authors declare no conflicts of interest in relation to this article.

Financing: The authors declare the non-existence of funding in relation to the present article.

Ethical responsibilities: All authors have confirmed the maintenance of confidentiality and respect for patients' rights in the author's responsibilities document, publication agreement and assignment of rights to EMERGENCIAS. The study was approved by the Research Ethics Committee of the Principality of Asturias (CEImPA Code no. 2021.214).

Article not commissioned by the Editorial Committee and with external peer review.

Acknowledgments: Gerencia de Urgencias, Emergencias y Transporte Sanitario. GUETS. Castilla-La Mancha Health Service. SESCAM. Servicio de Atención y Coordinación de Urgencias y Emergencias 112 de CastillaLa Mancha. Ministry of Finance and Public Administrations. General Directorate of Citizen Protection.

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