

Original

A mortality study of the last outbreak of yellow fever in Barcelona City (Spain) in 1870

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ABSTRACT

Background: The last outbreak of yellow fever in the city of Barcelona, Spain, was caused by a ship arriving from Cuba. The objective of this study was to describe and analyze the epidemic of 1870 by using the available mortality data.

Methods: The information on 1,235 deaths identified in the parochial registries was analyzed, using statistical and epidemiological procedures for epidemic outbreaks.

Results: Mortality due to yellow fever was 549.7 per 100,000 inhabitants. The temporal distribution of the deaths showed two peaks at the end of September and October with the last fatalities occurring in December 1870. The distribution of the fatalities in the city's neighborhoods was unequal. In La Barceloneta, in particular, more fatalities were found in the streets adjacent to the port than in the most remote streets ($r = 0.83$; $p < 0.0001$).

Conclusions: This study reveals a temporal bimodal mortality distribution for yellow fever during the outbreak, with a high impact in adult men and in the La Barceloneta neighborhood.

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Estudio de la mortalidad del último brote de fiebre amarilla en la ciudad de Barcelona (España) en 1870

RESUMEN

Objetivo: El último brote de fiebre amarilla en la ciudad de Barcelona, España, se originó a partir de un barco que venía de Cuba. El objetivo de este estudio es describir y analizar esa epidemia ocurrida en 1870, utilizando los datos disponibles de mortalidad.

Métodos: La información de las 1235 defunciones identificadas en los registros parroquiales se ha analizado utilizando los procedimientos estadísticos y epidemiológicos para brotes epidémicos.

Resultados: La tasa de mortalidad por fiebre amarilla fue de 549.7 por 100,000 habitantes. La distribución temporal de las muertes tenía dos modas en el final de septiembre y octubre, y los últimos muertos ocurrieron en diciembre de 1870. La distribución de las defunciones según los barrios de la ciudad fue desigual. En La Barceloneta, en particular, hubo más muertos en las calles adyacentes al puerto que en las más lejanas ($r = 0,83$; $p < 0,0001$).

Conclusiones: Este estudio muestra una distribución bimodal de la mortalidad por fiebre amarilla durante el brote, con un impacto alto en hombres adultos, y en el barrio de La Barceloneta.

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Palabras clave:

Fiebre amarilla

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Introduction

Yellow fever is an endemic and epidemic disease transmitted by the mosquito *Aedes aegypti* through the bite of females infected by a RNA virus named *Flavivirus*. Currently, yellow fever is spreading throughout several countries of Central and South America, and Africa, where it remains an endemic illness, with severe forms causing very serious liver damage and death. In those areas the disease affects about 200,000 people and causes an estimated 30,000 deaths annually^{1–3}. In 2006, 114 confirmed

cases of yellow fever causing 58 deaths were reported by WHO⁴. Even though the efficacy of yellow fever vaccine is almost 99%, yellow fever is still an important public health problem in developing countries due to underimmunization. In developed countries it is not longer a public health threat; in Barcelona city, the last epidemic outbreak of yellow fever occurred in 1870^{5–8}.

Due to geography, Barcelona has always been a commercial port city, with a harbor connecting it to other cities located on the Mediterranean coast, and other foreign countries. Barcelona's harbor trade activity was a vital and decisive element for its development, favoring its settlers to set up contact with other cultures, as well as to exchange political, economic and social ideas. As described by some authors, Barcelona settlers suffered from different diseases and plagues throughout history; yellow

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Figure 1. Map of Barcelona City in the second half of the 19th century.

fever was one of them^{9–12} and needs to be contextualized in the various outbreaks of yellow fever that ravaged Europe during the 18th and 19th centuries^{13–16}.

Barcelona, with a surface area of about 2000 square miles, is located almost 100 miles south of the Pyrenees Mountains, at latitude of 41° 23' N and longitude of 2° 11' E, between the Llobregat and Besòs rivers. In 1870, about 225,000 people lived in Barcelona, distributed among four neighborhoods: La Barceloneta, La Ribera, Gòtic, and El Raval¹⁷. Fig. 1 shows a map of the city and the harbor in 1862.

As it is now, in 1870 there were two rainy periods in March–April and October–November, a warm period in May–September and a fresh period in December–February. The average precipitation was 22 inches per year, days were predominantly sunny and temperatures were mild. For water storage, the population used large clay and metallic containers that were incompletely covered or closed, allowing mosquitoes to reproduce there⁸.

The epidemic outbreak started in August 1870, with the first fatality being a waiter of the ship *María* coming from Havana, Cuba. Pallarés reports: «... that the steam vessel was not inspected and it was permitted to enter the seaport of Barcelona even though there had already been some deaths during the trip. Its load wasn't inspected either; even several animal skins were delivered to a warehouse in Vermell Street».^{8(p227)} The objective of this epidemiological study is to describe and analyze the epidemic outbreak of yellow fever in the city of Barcelona in 1870, using the available mortality data.

Material and methods

Although the outbreak began in August and lasted until December, most deaths occurred between September and November of 1870. The deaths were documented in the parish registries, as the city's East cemetery. According to these records, 1264 deaths were identified with the diagnosis of *Typhus Icterodes*, *Typhus Icteroides*, or the acronym *Calentura Amarilla*^{5,8} during the period studied (August 1st through December 31st).

For purpose of this study, a database was prepared with the information available for each death: sex, age (in years), marital status (single, married or widow), date, profession, nationality, neighborhood (La Barceloneta, La Ribera, Gòtic and El Raval) and hospital where the deaths occurred (Santa Creu Hospital, the

military and the provisional one). The provisional hospital was located in a convent (Las Arrepentidas), 2 Km west from the city, and set up to manage the outbreak. Given the lack of information in some registries, there were some limitations to collect and analyze information on each death. Although the total number of deaths from yellow fever was 1,264, only 1,235 were analyzed in this study, since in 29 cases only the day when the death occurred was identified. For the neighborhood of La Barceloneta, the distance between the harbor's dock and the streets where the deaths occurred was also analyzed.

Statistical and epidemiological procedures were used to describe and analyze the epidemic outbreak according to characteristics of person, time, and place^{18,19}. The age and sex population pattern was estimated by linear interpolation from the censuses of 1860 and 1877¹⁷. Parametric and non-parametric tests were used to determine the specific hypotheses and the program SPSS v13.0 was utilized to analyze data²⁰. The significance level used was 5%.

Results

There were 1,235 deaths from yellow fever, representing 27.9% of all the deaths occurred between August 1st and December 31st. The crude mortality rate in Barcelona in 1870 was 40.3 deaths per 1,000 inhabitants, with a specific mortality from yellow fever being 549.7 deaths per 100,000 inhabitants.

Demographic characteristics

Of 1,235 deaths from yellow fever being studied, 767 occurred in men (62.10%) and 468 in women. The average age for all deaths was 37.5 years (standard deviation [SD] = 16.5). The average age at death was 35.7 years (SD = 16 years) among men and 40.6 years (SD = 16.8 years) among women ($t = -5.1$; $p = 0.0001$).

The mortality rate of yellow fever was 695.8 deaths per 100,000 inhabitants for men and 407.5/100,000 for women. Among the men who died, the 41–50 year age group was the most affected, with a mortality rate of 1,068.2/100,000 inhabitants. Among women, the highest mortality occurred among those over 60 years (874.8/100,000 inhabitants). The boys and girls between 1 and 10 years presented the lowest mortality rate (Table 1). The ratio between mortality rates from yellow fever in men versus women showed a different distribution by age groups.

The deaths occurred in sea-related activity workers were 181 (14.6%), the highest proportion observed. The average age of the people who died from yellow fever and were sailors (35.9 years, SD = 17.13 years) was lower than that of the people who died from yellow fever and were not sailors (38 years, SD = 16.6 years). However, these data are incomplete and refer only to the stated information on age and occupation ($t = -2.7$; $p = 0.0056$). There were only 5 fatalities among health workers.

Widows had the highest proportion of deaths among women (62.10%), while among men, there were the married ones (48.10%). Among all deaths, only 54 people (4.37%) had been born abroad, 49 of whom were men.

Temporal characteristics

The first death from yellow fever was notified on August 12th and the last one on December 31st of 1870. During the first half of that period, 821 deaths occurred (66.47%). The monthly distribution of the 1,264 deaths with the fatality day identified was as follows: in August, 20 deaths (1.58%), 425 in September (33.62%), 579 in October (45.81%), 236 in November (18.67%), and 4 in

Table 1
Distribution of deaths, census and mortality rate (per 100,000 inhabitants) from yellow fever in Barcelona City by age and sex, 1870

Age group (years)	Men			Women			Rate Ratio Men/Women	Total		
	Deaths	Census	Rate per 100,000 inhabitants	Deaths	Census	Rate per 100,000 inhabitants		Deaths	Census	Rate per 100,000 inhabitants
<1	6	2353	212.5	3	2342	128.1	1.66	9	4695	191.7
1 to 5	9	9402	74.4	4	9428	42.4	1.75	13	18830	69.1
6 to 10	5	8551	35.1	7	8744	80.1	0.44	12	17295	69.4
11 to 15	28	9098	318.7	13	9717	133.8	2.38	41	18815	217.9
16 to 20	72	10943	639.7	28	12489	224.2	2.85	100	23432	426.8
21 to 30	211	24925	882.6	82	24739	331.5	2.66	293	49664	589.9
31 to 40	156	17480	1006.9	107	18382	582.1	1.73	263	35862	733.4
41 to 50	143	12732	1068.2	100	12903	775.1	1.38	243	25635	947.9
51 to 60	70	8199	634.2	59	8679	679.8	0.93	129	16878	764.3
>60	67	6114	801.4	65	7430	874.8	0.92	132	13544	974.6
Total	767	109797	695.8	468	114853	407.5	1.71	1235	224650	549.7

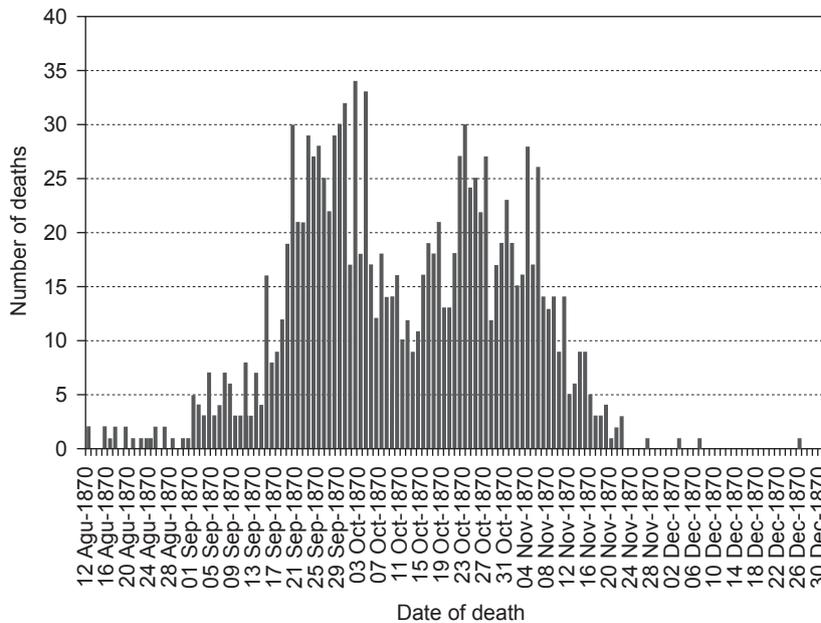


Figure 2. Epidemic curve of the yellow fever outbreak of Barcelona City in 1870.

December (0.32%). The curve of the deaths was bimodal: the first curve includes the time period between September 21st and October 4th and the second one encompasses the period between October 23rd and November 4th (Fig. 2). In terms of the days of week, Tuesdays had the highest (n = 275) number of deaths from yellow fever, whereas Wednesdays had the least fatalities (n = 123).

Regarding the 1,235 cases with any other information besides the day of death, no epidemiological association between temporal distribution of deaths by age, sex or profession was confirmed. The deaths among children under 10 years occurred only between September and November.

Geographical characteristics

The outbreak affected the four neighborhoods of Barcelona. The distribution of the fatalities was as follows: 276 in La Barceloneta, 315 in La Ribera, 93 in Gòtic, and 406 in El Raval. In 145 cases, the place of the death (11.74%) was not reported (Table 2). In the military hospital, located outside the city, 22 deaths occurred, all men; 16 of them were under age 25. During the

outbreak, only 13.7% of all deaths from yellow fever occurred in those hospitals.

The first fatalities in the city occurred in *Vermell Street* of the neighborhood of La Ribera⁸. In Major Street of the neighborhood of La Barceloneta, the street with the highest mortality, 35 deaths occurred; second to that, there was Allada Street of the neighborhood of La Ribera. In total, deaths from yellow fever occurred in 272 streets. No deaths from yellow fever were reported in the main street, Las Ramblas.

The analysis of available information of the deaths from yellow fever in the neighborhood of La Barceloneta showed that the streets closest to the port had greater mortality than the more remote ones (r = 0.83; p = 0.0001) (Table 3).

Discussion

This epidemic was the last outbreak of yellow fever in the city of Barcelona although it was not the last one in the Iberian Peninsula²¹. It is a good example of an infectious disease transmitted by a mosquito in the urban Mediterranean Europe in the 19th century^{14,15}. Two other epidemics of yellow fever had

Table 2
Distribution of deaths from yellow fever by neighborhood, hospital, and sex. Barcelona City, 1870

Neighborhood	Hospital deaths			Deaths outside the hospitals			TOTAL		
	Men	Women	Total	Men	Women	Total	Men	Women	Total
La Barceloneta	2	0	2	150	124	274	152	124	276
La Ribera	4	2	6	171	138	309	175	140	315
Gotic	0	0	0	54	39	93	54	39	93
El Raval	91	40	131	192	83	275	283	123	406
Missing	30	0	30	73	42	115	103	42	145
Total	127	42	169	640	426	1,066	767	468	1,235

Table 3
Distribution of deaths from yellow fever according to the distance from the harbour (La Barceloneta neighbourhood, 1870)

Street name	Distance from the harbour (in meters)	Number of deaths
Mar	193	32
Sant Elm	225	29
Sant Miquel	258	30
Pescadors	290	26
Comte de Santa Clara	322	14
Sevilla	354	12
Baluard	386	6
Mestrança	418	18
Meer	483	5
Pontevedra	539	4
Atlantida	573	14
Vinaros	605	4
Grau i Torres	669	5
Guitar	702	6

already occurred in that century in Barcelona (1803 and 1821)^{11,12,22}; other cities in Spain such as Cadiz, Sevilla and Jerez were likewise hit between 1800 and 1803²¹. In Europe, other cities, all located on the coast, were affected in the 19th century by yellow fever: Brest and Saint Nazaire in France, Lisboa in Portugal, and Swansea and Southampton in the United Kingdom^{13,14,16,23}. This study is limited by the fact that there were registered 1,264 deaths, but only 1,235 fatalities with available information such as age, sex or other variables²⁴.

The mortality rate of this outbreak of yellow fever in the city of Barcelona was 549.7 per 100,000 inhabitants. The previous episode of yellow fever in Barcelona had been in 1821, affecting 80,000 inhabitants living inside the city and 25,000 living outside^{9–12}. Considering the yellow fever's lethality, which was between 10% and 50%, the estimated number of patients in the 1870s outbreak would be between 2,500 and 12,350 (up to 5.50% of the Barcelona population), a smaller impact than the episode of 1821^{12,13}. Both are examples of epidemics produced in European maritime cities as a consequence of the trade with the Caribbean and Latin America. Similarly, in 1870, 665 people died from yellow fever in Havana, Cuba^{12,25,26}; in the same year, a major epidemic of yellow fever occurred in Buenos Aires with 14,000 deaths²⁷.

The average age of the deaths in the Barcelona outbreak confirms the predominant impact on adults, as described by other authors²⁸. In particular, the average age in men was lower than in women, contrasting with the results observed in the outbreak occurring in Swansea in 1865, where the average age in men was 29.7 years whereas in women it was 27¹³.

The epidemic curve, as seen in Fig. 2, indicates clearly its bimodal form. The first epidemic wave affected the people working in the ship *María* as well as the people involved in dock activities, especially in the neighborhoods of La Barceloneta and La Ribera, which were the places where the outbreak started. The

authorities were not aware of the magnitude of the problem until September, when the outbreak was at its peak. The second epidemic wave of this bimodal distribution seems to coincide with the expansion of the outbreak to the rest of the city⁸.

The distribution of some neighborhoods in Barcelona in 1870 was similar to the present, yet not exactly the same. For example, in La Barceloneta, located close to the port, the same grid pattern can currently be observed in that neighborhood. In contrast, the Via Laietana Street, which nowadays separates the neighborhoods of La Ribera and Gotic, did not exist in 1870^{29–31}, facilitating any type of exchange between them. The outbreak initially affected the neighborhoods of La Barceloneta and La Ribera and then spread to the rest of the city. There were other areas affected outside the city (Gracia and Hortafranchs), but these cases have not been included in this study. In fact, La Barceloneta was evacuated and many of its inhabitants were transferred provisionally to neighboring localities as La Colonia Montalegre, located in Tiana⁸.

A limitation of this study is the lack of specific census by neighborhood in 1870. The distribution of the yellow fever fatalities during the outbreak was not uniform either within or between neighborhoods. There are records of deaths from yellow fever in 272 streets of Barcelona city in 1870. The fact that no deaths were registered in Las Ramblas Street and the few deaths registered in the neighborhood Gòtic suggests that the low social classes were the most affected. This hypothesis, however, has not been corroborated, given the limited availability of information on this epidemiological event⁸, although other authors mentioned this fact in the second half of the 19th century^{32,33}. A high linear correlation between a greater mortality in the streets adjacent to the port in the neighborhood of La Barceloneta suggests a higher risk of suffering and dying from yellow fever in the areas nearby the docks; this finding is consistent with the evidence that the mosquito *Aedes aegypti* rarely moves more than 100 meters³⁴ (Table 3).

Finally, the cold weather conditions and the appropriate hygienic measures adopted by health authorities, regarding not only the harbor but also the neighborhoods, completely eliminated the outbreak in December 1870. A report was published in 1871–72⁵, and one of its indirect consequences was the acceleration of the expansion of the city with a new neighborhood, called Eixample, planned by the urbanist Ildefonso Cerdà in 1854⁶.

In conclusion, the mortality distribution of the last urban epidemic of yellow fever occurred in Barcelona in 1870 presented a bimodal epidemic curve, with a greater impact in adult men and the La Barceloneta quarter.

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Contributors

JCS directed the study design, data analysis and wrote a substantial part of it. MRPF collected and organized data and contributed building crucial information. RAH organized data and contributed writing previous documents. CNA discussed, wrote and revised previous versions. RSL contributed to the discussion and revision of the article.

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