Age and Gender Perspective of COVID-19 Mortality in San Diego County

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Abstract
Objective: To examine COVID-19 mortality from age and gender perspectives, and to investigate how COVID-19 mortality risk differs between men and women across different age groups in San Diego.

Methods: The daily cumulative COVID-19 cases and deaths data in San Diego from March 2020 to September 2021 were used in the study. Case fatality rates were calculated for men vs. women with corresponding relative risk. Furthermore, mortality rates (per 100,000 population) stratified by age and gender with corresponding relative risks for men vs. women across the age groups were also calculated.

Results: As of September 12, 2021, a total of 345,648 COVID-19 cases and 3,981 deaths reported in San Diego.

1. COVID-19 is substantially more dangerous not only for the elderly but also for middle-aged and upper middle-aged adults. Among the COVID-19 deaths, 2.5% were younger than 45 years old, 43% were aged 45-74, and 54.5% were 75+.

2. Men (59.8%) had more deaths due to COVID-19 than women (40.2%). The COVID-19 mortality risk was significantly higher for men than women with a case fatality rate (CFR) of 1.42% in men vs. 0.91% in women (relative risk: 1.56, 95% CI: 1.46, 1.66), and with mortality rate (per 100,000) of 141.7 in men vs. 96.5 in women (relative risk: 1.47, 95% CI: 1.38, 1.56).

3. COVID-19 mortality rates in men were consistently higher than women across all age groups. The greatest gender differences were in age groups of 30-39 and 40-49 (relative risks are above 3). The gender differences decreased thereafter with the next smallest gender difference in the age group of 80+.

Conclusions: This study demonstrated a similar pattern of COVID-19 mortality by age and gender in San Diego county compared to the global data. By identifying the most vulnerable populations in the community, healthcare personnel can ensure the better targeting of prevention and intervention efforts to improve chances of survival for these high-risk groups both during the pandemic and beyond.

Key Words: COVID-19, mortality risk, case fatality rate, mortality rate, *p*-value, relative risk, age, gender, healthcare

1. Introduction

Since December 2019, the Coronavirus disease 2019 (COVID-19) [1] caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has rapidly affected the whole world. The pandemic was recognized by the World Health Organization on March 11, 2020. As of September 12, 2021, more than 225 million COVID-19 cases and 4.6 million deaths have been reported globally. The United States has the leading number of cases, with over 42 million cases and over 683K deaths. Furthermore, California had the largest number of cases and deaths in the U.S. It has also increased rapidly in San Diego which had 345,648 cases and 3,981 deaths reported as of September 12, 2021 [2].

Table 1: COVID-19 cases and deaths statistics as of September 12, 2021

	Total Cases	**Total Deaths**
World	225,784,231	4,649,620
United States	42,061,837	683,265
California	4,494,202	67,263
San Diego	**345,648**	**3,981**

There are a variety of risk factors identified for COVID-19 mortality, the most important of which are old age and underlying health conditions. Scientists noted early on that the risk of dying from COVID-19 is strongly associated with age and that COVID-19 fatality increases with age [3, 4, 5, 6]. It is clear that older age is a major risk factor for COVID-19 mortality, particularly for people who are older than 70 years [7, 8, 9, 10, 11] as their mortality rates are much higher.

In addition to age, gender is also a strong risk factor for COVID-19 mortality. Males with COVID-19 have a higher mortality rate than females as indicated by global data. This may be due to various reasons, such as biological (genetics and immunology), psychological, lifestyle, and gender behavioral factors, as well as certain attitudes toward COVID-19. Globally, almost all of the data reported a higher proportion of deaths among men than among women [12, 13, 14, 15, 16, 17, 18].

Furthermore, several research studies done nationally and globally with both age and gender perspectives examined the gender differences in COVID-19 mortality across different age groups. They investigated the risks based on the interaction of age and gender [19, 20, 21] in different areas of the world, showing that male COVID-19 mortality rates are overall higher than those of females across all age groups.

As of September 12, 2021, 345,648 COVID-19 cases and 3,981 deaths have been reported in San Diego. More than one year into the pandemic, there is now sufficient demographic data to establish key facts about the relationship between age, gender, and COVID-19 mortality. It is important to understand COVID-19's impacts across gender and age groups in our community. These factors will help to identify the most vulnerable populations in our community during the pandemic, further ensuring better targeting of prevention and intervention efforts to protect and improve chances of survival for the high-risk groups.

2. Methods

2.1 Data and Study Population

The data in the analysis were collected from San Diego county, consisting of COVID-19 cases and deaths by ten-year age groups (0-9, 10-19, ……80+) as well as by gender. Cumulative individual death data with age and gender information were also available [22].

The analysis includes 3,981 individuals who died due to COVID-19, from the first death in San Diego on March 21, 2020 to September 12, 2021.

2.2 Statistical Methods

Summaries of the descriptive statistics were generated for the variables. Age was not normally distributed and was therefore summarized using median (with interquartile range IQR) and compared using the Wilcoxon Rank Sum test. Categorical variables (age group and gender) were summarized using frequency tables and analyzed using the Fisher's Exact test. P value < 0.05 (two-tailed) was considered to be statistically significant.

Distributions of the cases and deaths by gender as well as by age group respectively were summarized. Gender-specific case fatality rates (CFR) and mortality rate (per 100,000), respectively, were calculated for men vs. women with corresponding relative risks and 95% confidence intervals. Age-specific case fatality rate (CFR) and mortality rate (per 100,000), respectively, were also calculated for each age group.

Age and gender-stratified COVID-19 death data were summarized to investigate how COVID-19 mortality risk differs between men and women across different age groups. The mortality rate (per 100,000) for each age group (S) was calculated for men and women separately. The relative risk (gender mortality ratio) and 95% confidence interval for each age group (S) were also calculated.

The case fatality rate was calculated as follows:

$$\text{Case Fatality Rate(CFR \%)} = \frac{\text{Number of deaths}}{\text{Number of cases}}$$

The mortality rate (per 100,000) for each age group, S, was calculated separately for men and women as follows:

$$\text{Mortality Rate (per 100,000) for S} = \frac{\text{Total number of death in S}}{\text{Total population (in 100,000) of S}}$$

The relative risk (gender mortality ratio) for each age group, S, was calculated as follows:

$$\text{Relative Risk (Gender mortality ratio) for S} = \frac{\text{Men mortality rate for S}}{\text{Women mortality rate for S}}$$

2.3 Software

Python 3 in Anaconda Jupyter Notebook (https://www.anaconda.com) and R version 3.6.3 (http://www.r-project.org) in RStudio were used

3. Results

As of September 12, 2021, a total of 345,648 COVID-19 cases with more women (51.2%) than men (48.8%) have been reported in San Diego. The first death due to COVID-19 was on March 21, 2020. A total of 3,981 COVID-19 deaths with more men (59.8%) than women (40.2%) have been reported. The COVID-19 mortality risk was significantly higher for men than women with case fatality rate (CFR) of 1.42% in men vs. 0.91% in women (relative risk: 1.56, 95% CI: 1.46, 1.66), and with mortality rate (per 100,000) of 141.7 in men vs. 96.5 in women (relative risk: 1.47, 95% CI: 1.38, 1.56). (Table 2).

Table 2: Distribution of the cases and deaths by gender as of September 12, 2021

Gender	Cases (%)	Deaths (%)	Mortality Rate	CFR (%)
Female	175595 (51.2%)	1600 (40.2%)	96.50	0.91%
Male	167561 (48.8%)	2381 (59.8%)	141.70	1.42%
Unknown	2492			

Overall, the median age of San Diego COVID-19 deaths was 77 years old [IQR 65-86]. Women were overall older than men (median/IQR: 81 [69-89] vs. 73 [63-83], P value < 0.001). Among 3,981 individuals who died due to COVID-19, 98 (2.5%) were younger than 45 years old, 1712 (43%) were aged 45-74 years, and 2171 (54.5%) were 75+. Table 3 shows the detailed distribution of COVID-19 cases and deaths by age groups. 85% of cases were mostly among individuals under 60 years old. In contrast, 86% of deaths were reported among those aged 60+. The overall case fatality rate is 1.15% and the mortality rate per 100,000 population is 119.25. The age-specific death proportions, case fatality rate (CFR), and mortality rate all increased with age which illustrates a steeper progression of mortality with age. The age-specific CFR are very low for children and young adults, but increase to 0.26% for age group of 40-49, and then progressively higher up to 0.82% for age group 50-59, 2.80% for ages 60-69, 7.02% for age group 70-79, and 18% for ages 80+. The mortality rate per 100,000 population shows the similar pattern. These results demonstrate that COVID-19 has substantial mortality risk for middle-aged and upper middle-aged and even higher risks for elderly individuals in San Diego (Table 3, Figure 1, Figure 2).

Table 3: Distribution of the cases and deaths by age groups as of September 12, 2021

Age Group	Cases (%)	Deaths (%)	Mortality Rate	CFR (%)
Overall	345648 (100%)	3981 (100%)	119.25	1.15%
0-9	21517 (6.2%)	0	0	0%
10-19	39790 (11.5%)	2 (0.1%)	0.49	0.01%
20-29	77621 (22.5%)	18 (0.5%)	3.43	0.02%
30-39	62591 (18.1%)	38 (1.0%)	7.50	0.06%
40-49	48516 (14.0%)	125 (3.1%)	29.74	0.26%
50-59	44176 (12.8%)	364 (9.1%)	90.05	0.82%
60-69	28449 (8.2%)	797 (20.0%)	228.90	2.80%
70-79	13354 (3.9%)	937 (23.5%)	448.85	7.02%
80+	9447 (2.7%)	1700 (42.7%)	1427.62	18.00%
Unknown	187			

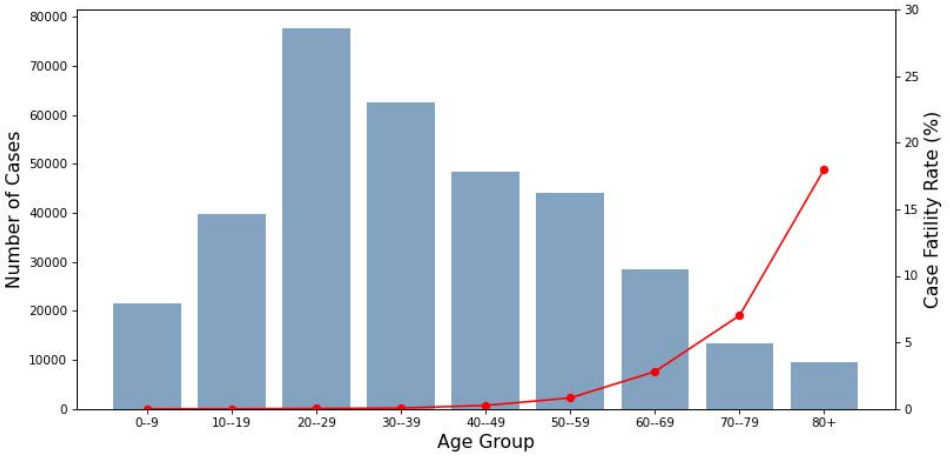

Figure 1: Distribution of cases and case fatality rate (CFR %) by age groups

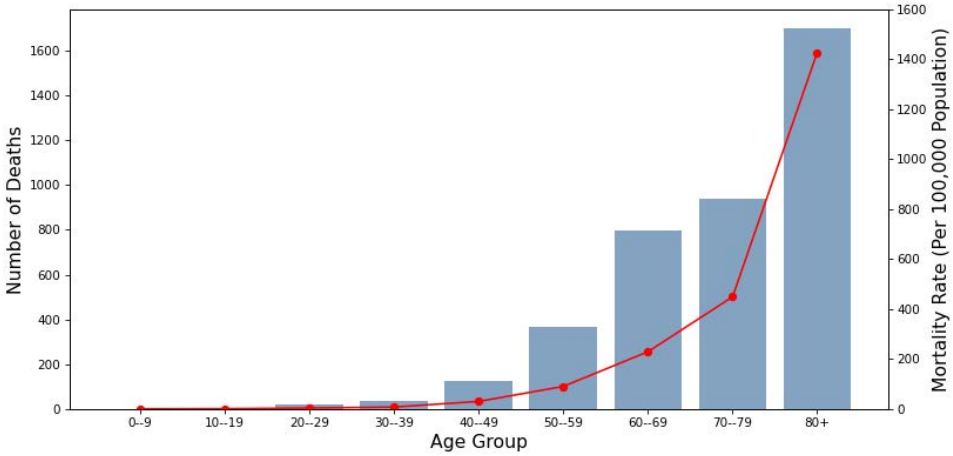

Figure 2: Distribution of deaths and mortality rate by age groups

The deaths percentages increased in both genders as the age groups advanced. And also, the percentage of male deaths is higher than female deaths in each age group except 80+ (Figure 3, Figure 4).

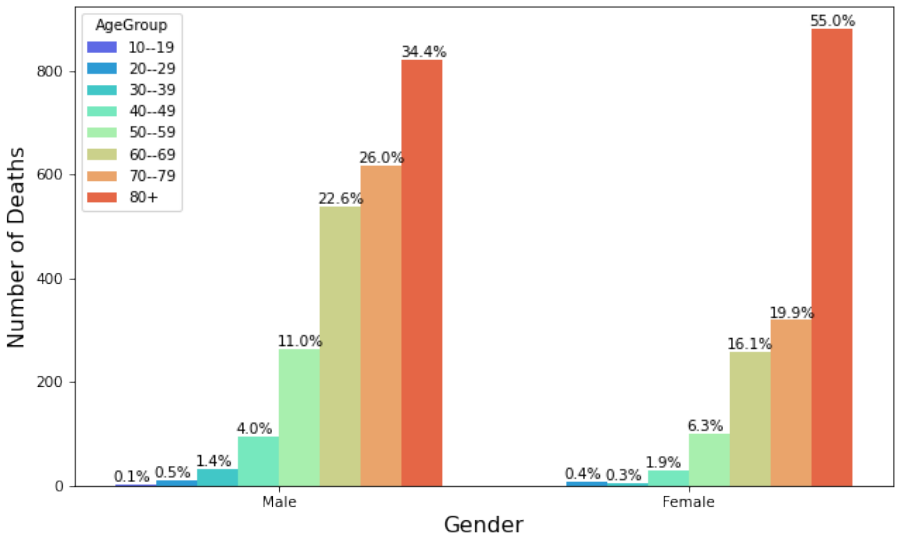

Figure 3: Age distribution of deaths by gender

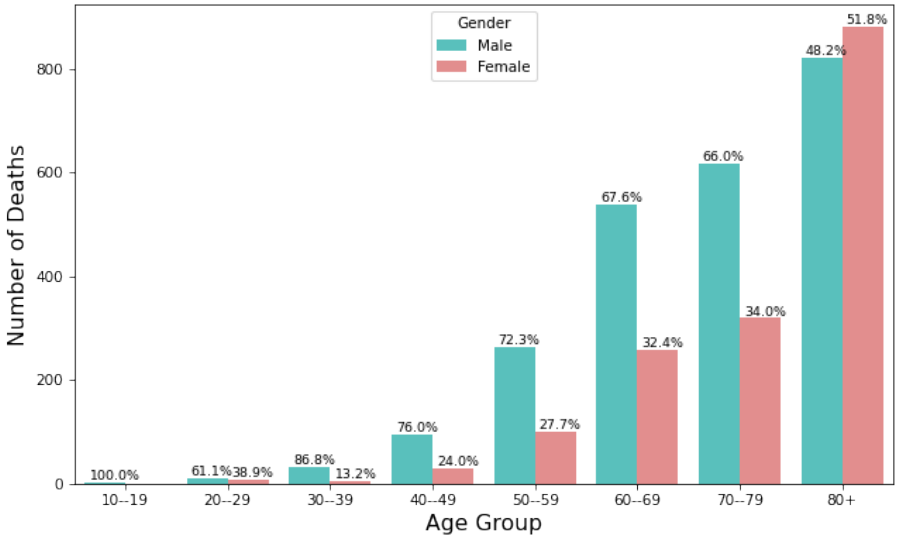

Figure 4: Gender distribution of deaths by age group

Overall, the male COVID-19 mortality rate (per 100,000) was 141.7, which was significantly higher than the female mortality rate of 96.5 (relative risk: 1.47, 95% confidence interval [CI]: 1.38, 1.56). Male mortality rates were also consistently higher than those of female across all age groups, with the greatest gender difference was in age groups of 30-39 and 40-49 (relative risks are above 3). Gender differences decreased thereafter with the next smallest gender difference in the age group of 80+ (Table 4, Figure 5, Figure 6).

Table 4: Distribution of deaths by age group and gender as of September 12, 2021

Age Group	Male		Female		Relative Risk (Gender Mortality Ratio)
	Death	Mortality Rate (95% CI)	Death	Mortality Rate (95% CI)	
Overall	2381 (100%)	141.70 (136.01, 147.39)	1600 (100%)	96.50 (91.77, 101.23)	1.47 (1.38, 1.56)
0--9	0	0	0	0	
10--19	2 (0.1%)	0.94 (0, 2.25)	0	0	
20--29	11 (0.5%)	3.88 (1.59, 6.18)	7 (0.4%)	2.89 (0.75, 5.03)	1.34 (0.07, 2.62)
30--39	33 (1.4%)	12.63 (8.32, 16.94)	5 (0.3%)	2.04 (0.25, 3.83)	6.19 (0.37, 12.02)
40--49	95 (4.0%)	44.78 (35.77, 53.78)	30 (1.9%)	14.41 (9.25, 19.57)	3.11 (1.83, 4.38)
50--59	263 (11.0%)	134.91 (118.61, 151.22)	101 (6.3%)	48.26 (38.85, 57.67)	2.80 (2.15, 3.44)
60--69	539 (22.6%)	313.67 (287.19, 340.15)	258 (16.1%)	146.30 (128.45, 164.15)	2.14 (1.83, 2.46)
70--79	618 (26.0%)	650.82 (599.51, 702.13)	319 (19.9%)	280.32 (249.56, 311.08)	2.32 (2.01, 2.64)
80+	820 (34.4%)	1732.88 (1614.27, 1851.49)	880 (55.0%)	1226.33 (1145.30, 1307.35)	1.41 (1.28, 1.55)

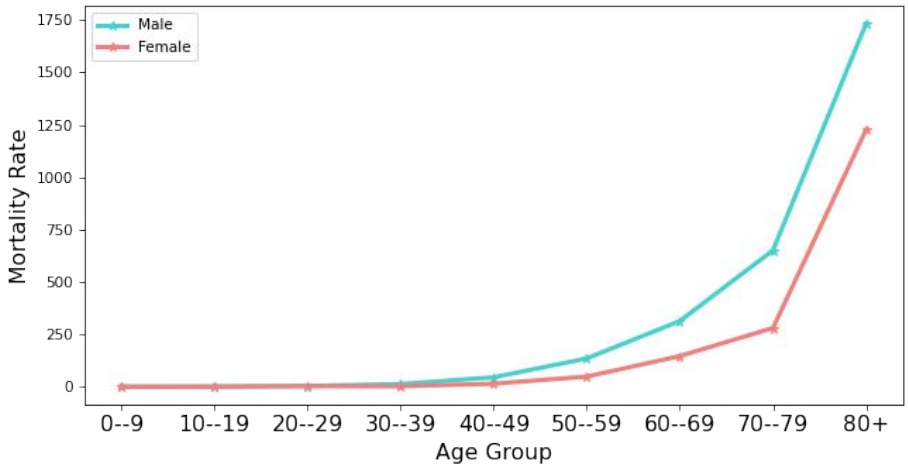

Figure 5: Mortality rate (per 100,000) by age group and gender

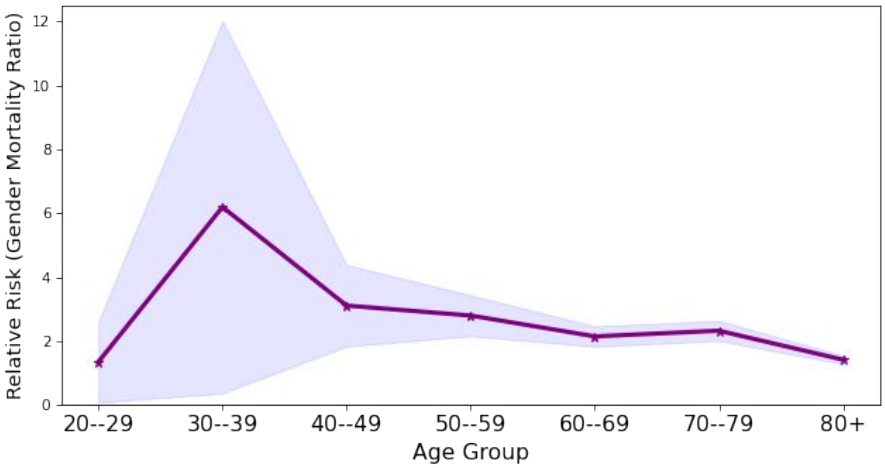

Figure 6: Relative risk (Gender Mortality Ratio)

4. Discussion

By using San Diego COVID-19 daily cumulative death data by age and gender, it demonstrates that the risk of death increased with age, and COVID-19 is substantially dangerous not only for the elderly but also for middle-aged and upper middle-aged adults. Overall, men had higher COVID-19 mortality than women across all age groups. The COVID-19 pandemic is still unfolding and the data is still evolving. However, by examining the cumulative individual mortality data for more than a year, a similar mortality pattern with the world by age and gender was observed in San Diego.

As of September 12, 2021, among the 3,981 individuals who died due to COVID-19 in San Diego, 98 (2.5%) were younger than 45 years old, 1,712 (43%) were aged between 45 and 74, and 2,171 (54.5%) were 75+. This is consistent with CDC's U.S. COVID-19 deaths findings: "Nearly 40 percent of U.S. COVID-19 deaths have occurred among those ages 45 to 74 years, while almost 60 percent have occurred among those over 75 years old. By contrast, children and young adults (less than 45 years old) account for less than 3 percent of U.S. COVID-19 deaths." Furthermore, the age-specific COVID-19 case fatality rate (CFR) in San Diego was very low for children and young adults, but increased to 0.26% for age group of 40-49, and progressively more to 0.82% for age group of 50-59, 2.8% for age group of 60-69, 7.02% for age group of 70-79, and 18% for age 80+. All these results indicate that COVID-19 is hazardous not only for the elderly but also for middle-aged and upper middle-aged adults in San Diego, which is consistent with a meta study led by Dartmouth [23, 24].

Systematic reviews and global studies suggested higher COVID-19 mortality risk in men than in women. Globally, men are about 60% more likely to be severely ill or to die from complications of COVID-19 than women [12, 13, 14, 15]. There were higher proportion of deaths among men (between 59% and 69%) than among women for almost all of the data reported for gender [12]. The mortality data in San Diego showed a similar pattern with the global data. As of September 12, 2021, though there were more confirmed cases in women (51.2%) than in men (48.8%) in San Diego, men (59.8%) had more deaths due to COVID-19 than women (40.2%). The COVID-19 mortality risk was significantly higher for men than women with a case fatality rate (CFR) of 1.42% in men vs. 0.91% in women (relative risk: 1.56, 95% CI: 1.46, 1.66), and with mortality rate (per 100,000) of 141.7 in men vs. 96.5 in women (relative risk: 1.47, 95% CI: 1.38, 1.56).

There are several possible factors that place men at a higher mortality risk for COVID-19 than women. There are biological factors such as higher expression of receptors for coronavirus (ACE 2) in males than females and sex-based immunological differences driven by sex hormone and X chromosome. There are also gender behavioral and lifestyle factors, such as higher drinking and smoking levels in men, which could cause more comorbidities including cardiovascular disease and lung disease hypertension. Furthermore, the differences of attitude toward the pandemic between men and women would eventually affect preventive actions such as face mask wearing, handwashing, and social distancing [16, 17, 18].

Furthermore, a number of national and global research studies demonstrated that male COVID-19 mortality risk was generally higher than that of females across all age groups [19, 20, 21]. San Diego's mortality data indicated the same trend with male COVID-19 mortality rates consistently higher than female mortality rates across all age groups, with the highest gender difference measured by relative risks above 3 in age groups of 30-39 and 40-49, then decreasing with next smallest gender difference in the age group of 80+.

Examining population data on daily cumulative COVID-19 deaths in San Diego county by age and gender, as well as their interactions, showed that COVID-19 is substantially dangerous not only for the elderly but also for middle-aged and upper middle-aged adults, particularly for men who had consistently higher COVID-19 mortality risk than women across all age groups. By identifying these most vulnerable and high-risk populations in our communities during the pandemic, clinical care and public health personnel can

ensure better targeting of prevention and intervention efforts to improve the chances of survival for them.

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