Effect of COVID-19 on hospital visits in Ningbo, China: an interrupted time series analysis

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Abstract

Background: Unprecedented rigorous public health measures were implemented during the COVID-19 epidemic, but it is still unclear how the intervention influenced hospital visits for different types of diseases. We aimed to evaluate the impact of the intervention on hospital visits in Yinzhou District, Ningbo, Zhejiang Province, China.

Methods: We conducted an interrupted time series analysis from January 1st, 2017 to September 6th, 2020 based on the Yinzhou Health Information System in Ningbo, Zhejiang province. The beginning of the intervention was on January 23rd, 2020, and thus, there were 160 weeks before the intervention and 32 weeks after the implementation of the intervention. Level changes between expected and observed hospital visits in the post-intervention period were estimated using quasi-Poisson regression models.

Results: Compared with the expected level, there was an estimated decrease of -22.60% (95% CI: -27.53%, -17.36%) in the observed total hospital visits following the intervention. Observed hospital visits for diseases of the respiratory system were found to be decreased dramatically (-62.25%, 95% CI: -65.62%, -58.60%). However, observed hospital visits for certain diseases were estimated to be increased, including diseases of the nervous system (+11.17%, 95% CI: +3.21%, +19.74%), diseases of pregnancy, childbirth and the puerperium (+27.01%, 95% CI: +17.89%, +36.85%), certain conditions originating in the perinatal period (+45.05%, 95% CI: +30.24%, +61.56%), and congenital malformations deformations and chromosomal abnormalities (+35.50%, 95% CI: +21.24%, +51.45%).
**Conclusions:** Our findings provided scientific evidence that cause-specific hospital visits evolved differently following the intervention during the COVID-19 epidemic.

**Keywords:** COVID-19; Hospital Visits; Interrupted time series analysis
Introduction

In late December 2019, patients with unknown causes of pneumonia broke out in Wuhan, China [1]. The novel coronavirus disease, later known to be COVID-19, spread across China although proactive public measures were taken to combat the disease. The first case of COVID-19 in Zhejiang Province was diagnosed on January 17th, 2020 [2], and the first-level public health emergency response was officially activated on January 23rd, 2020. Subsequently, unprecedented rigorous public health interventions were implemented, including quarantines, stay-at-home orders, and travel restrictions [3]. People practiced social distancing, self-isolation, cleaning hands frequently, and wearing masks under the circumstances [4].

The intervention caused significant disruptions in daily life, and also affected the number of hospital visits. A series of studies [5-7] reported sharp drops in the number of persons seeking emergency medical care during the COVID-19 outbreak. For instance, a nationwide study in the United States found that emergency department visits during the early pandemic period (March 29th to April 25th, 2020) were 42% lower than that during the same period a year earlier [7]. An interrupted time series (ITS) analysis in France indicated that the number of pediatric emergency department visits and related hospital admissions decreased by 68% and 45% after the lockdown [8]. A Chinese study showed that dental urgency visits decreased by 38% at the beginning of the COVID-19 epidemic than before [9].

Given the altered behavioral patterns and evolution of hospital visits during the COVID-19 epidemic, we hypothesized that the intervention could have an impact on the supply of medical service, people’s willingness to seek medical help, the incidence of certain
diseases, and thus, affect hospital visits for different types of diseases. However, to date, limited studies can be available to systematically evaluate the impact of the intervention during the COVID-19 epidemic on total and cause-specific hospital visits in China.

Herein, we conducted an ITS analysis to quantify the effect of the intervention on hospital visits in Yinzhou District, Ningbo, Zhejiang Province, China. Our findings could not only reveal change patterns of hospital visits during the COVID-19 epidemic period but also provide evidence-based references for future disease control and prevention.

Methods

Design and Source of Data

We conducted an ITS analysis from January 1st, 2017 to September 6th, 2020 based on the Yinzhou Health Information System (YHIS) [10] in Ningbo, Zhejiang province. YHIS was composed of residents' healthcare records, Chronic Diseases Recording System, and Hospital Information System, making it possible to obtain comprehensive and timely health information for each resident. Hospital Information System, including date of hospital visits, diagnosis of disease, and International Classification of Diseases, Revision 10 (ICD-10) was used for our analysis. Diagnosis of disease was classified according to ICD-10 and the number of hospital visits was grouped by calendar weeks for each year. This study was approved by the Institutional Review Board of the Zhejiang University School of Medicine. Informed consent was not required because anonymous and de-identified information was used for our analysis.

Outcome

The main outcome was the evolution of the number of total and cause-specific hospital visits
before and after the implementation of the intervention in response to the COVID-19 epidemic in Zhejiang, China.

**Statistical analysis**

ITS analysis with a quasi-Poisson regression model was used to estimate changes in hospital visits following the intervention during the COVID-19 epidemic. Several variables were entered into the model [11]: (i) the time elapsed since the start of the study (\(T\), ranged from 1 to 192, representing a total of 192 weeks during the study period); (ii) a dummy variable indicating the intervention owing to the COVID-19 epidemic (\(X_t\), coded 0 indicated the pre-intervention period and 1 indicated the post-intervention period); (iii) Fourier terms modeling seasonality patterns (Fourier) [12]; (iv) 1-week lagged residuals fitting the autocorrelation of time series (\(\varepsilon\)). In our study, we only considered the short-term changes in level (not the long-term changes in trend), and used the following segmented regression model:

\[
\log(Y_t) = \beta_0 + \beta_1 T + \beta_2 X_t + \text{Fourier} + \varepsilon
\]

Where \(Y_t\) is the total or cause-specific hospital visits, \(\beta_0\) is the intercept, \(\exp(\beta_1)\) is the changes in hospital visits with a time unit change, and \(\exp(\beta_2)\) is the changes in levels following the intervention. Fourier terms were determined by auto Arima models and \(\varepsilon\) was determined by the models without residuals. In our analysis, the beginning of the intervention was defined as a time point on January 23\(^{rd}\), 2020, when Zhejiang Province officially activated the first-level public health emergency response. And thus, the pre-intervention period was from January 1\(^{st}\), 2017 to January 22\(^{nd}\), 2020 (\(T=1\) to \(T=160\)) and the post-intervention period was from January 23\(^{rd}\), 2020 to September 6\(^{th}\), 2020 (\(T=161\) to...
T=192) (i.e. there were 160 weeks before the intervention and 32 weeks after the implementation of the intervention).

The validity of our regression model was checked by plotting residuals, autocorrelation functions (ACF), and partial autocorrelation functions (PACF). All statistical tests were two-sided and \( p \)-value<0.05 was considered statistically significant. All statistical analyses were performed using R v4.0.1 (http://www.R-project.org). All data analyses were conducted in 2020.

**Results**

A total of 48,574,128 hospital visits (42,113,607 for pre-intervention period and 6,460,521 for post-intervention period) were identified from the YHIS (Table 1). Overall, decreased total hospital visits per week were observed during the post-intervention period. For cause-specific classification, diseases of the respiratory system (ICD-10: J00-J99), the circulatory system (I00-I99), and the digestive system (K00-K93) were the top 3 hospital visits in total during the pre-intervention period whereas diseases of the circulatory system (I00-I99), the digestive system (K00-K93), and the musculoskeletal system and connective tissue (M00-M99) accounted for the top 3 during the post-intervention period.

Regression analysis of weekly data indicated a sharp decrease between expected and observed values for total hospital visits after the implementation of the intervention (-22.60%, 95%CI: -27.53%, -17.36%) (Table2, Figure1). Similar results were observed for most of the cause-specific hospital visits (Table2, Figure 2). The diseases of the respiratory system (J00-J99), certain infectious and parasitic diseases (A00-B99), and symptoms, signs, and abnormal clinical and laboratory findings, not elsewhere classified (R00-R99), ranking as the
top 3 decreased cause-specific hospital visits, remarkably decreased over 60%, 29%, and 18% as compared with the expected values, respectively. However, hospital visits for several diseases were found to be significantly increased, including +11.17% (95% CI: +3.21%, +19.74%) for diseases of the nervous system (G00-G99), +27.01% (95% CI: +17.89%, +36.85%) for diseases of pregnancy, childbirth and the puerperium (O00-O99), and +45.05% (95% CI: +30.24%, +61.56%) for certain conditions originating in the perinatal period (P00-P96) and +35.50% (95% CI: +21.24%, +51.45%) for congenital malformations deformations and chromosomal abnormalities (Q00-Q99), respectively (Table 2, Figure 3).

No significant changes were observed for endocrine, nutritional and metabolic diseases (E00-E90), mental and behavioral disorders (F00-F99), diseases of the circulatory (I00-I99), digestive (K00-K93) and genitourinary (N00-N99) system, injury, poisoning, and certain other consequences of external causes (S00-T98) and factors influencing health status and contact with health services (Z00-Z99) (Table 2, Supplementary Figure 1).

Discussion

Statement of principal findings

In this ITS study of 48,574,128 hospital visits, we observed a significant decrease between observed and expected values in total hospital visits during the post-intervention period. Hospital visits for the diseases of the respiratory system (J00-J99) were found to be decreased dramatically while 4 kinds of diseases were observed to be increased. Our results provided strong evidence that there was a significant impact of intervention during the COVID-19 epidemic on hospital visits.

Strengths and limitations
In this quasi-experiment study, we evaluated the impact of the intervention during the COVID-19 epidemic on all types of hospital visits, which was limited reported before. However, Several limitations of our study should be acknowledged. Firstly, several time-varying confounders that may affect hospital visits, such as air pollution and meteorological factors, were not included in our regression models although Fourier terms were used to fit the seasonality. Secondly, we did not consider the long-term trend in hospital visit changes because our observation period was not long enough. Finally, data on hospital visits were only extracted from one district of Ningbo, and a nationwide study is needed to further confirm our findings.

**Interpretation within the context of the wider literature**

During the COVID-19 epidemic, unprecedented rigorous public health measures were implemented, which may unintentionally affect established integrated care systems [5]. In China, some departments in hospitals, such as the dental department, otorhinolaryngology department, were suspended while emergency services were provided only. On the other hand, people’s fear of the possible risk of COVID-19 infection might contribute to hospital access discouraged [13]. The decrease of total and certain cause-specific hospital visits could be partly explained by the above reasons. However, the dramatic decrease of hospital visits for certain infectious and parasitic diseases (A00-B99) and diseases of the respiratory system (J00-J99) may also be attributable to lockdown measures, which could reduce numerous infectious diseases sharing the same transmission routes with COVID-19. A study in France indicated that because of school closure and national lockdown measures, there was a significant decrease in common cold, gastroenteritis, bronchiolitis, and acute otitis [8].
Furthermore, individual lifestyles have altered during the COVID-19 epidemic. For instance, people were recommended to wear masks, which were expected to reduce the incidence of airborne transmitted diseases. Patel and his colleagues demonstrated that using surgical masks was an effective measure to prevent the spread of respiratory infection [14], and as a physical barrier, wearing masks could be beneficial to avoid allergens and prevent allergic rhinitis [15].

Not all hospital visits for cause-specific diseases were found to be decreased, and we found a significant increase in hospital visits for four types of diseases. Of note, apart from the diseases of the nervous system (G00-G99, slightly increased), hospital visits for three types of diseases remarkably increased, including diseases of pregnancy, childbirth, and the puerperium (O00-O99), certain conditions originating in the perinatal period (P00-P96), and congenital malformations deformations, and chromosomal abnormalities (R00-R99). These findings could be explained by the impact of the intervention on prenatal care during the COVID-19 epidemic. Several studies have shown that pregnant women could not go to the hospital unless in an emergency due to the lockdown in the early COVID-19 pandemic all over the world [16, 17]. In China, a web-based survey indicated that over 40% of respondents feared in-hospital antenatal visits, and more than 50% considered or decided to cancel or postpone their appointments [18]. Although online antenatal care programs were proposed, not all pregnant women used the internet, and online gestational information needed to be screened. A drive-through prenatal care model was developed in the United States, and thus, pregnant women would remain in their automobiles while being assessed by the health care professional [19].
Although we observed no effect of the intervention on hospital visits for most of the non-communicable diseases (NCDs), such as endocrine, nutritional and metabolic diseases (E00-E90), mental and behavioral disorders (F00-F99), diseases of the circulatory system (I00-I99), and diseases of the digestive system (K00-K93), we can never ignore the long-term effect of the intervention. Due to the short observed period, we were not able to detect the changes in the long-term trend of hospital visits. As we know, the intervention measures, such as stay-at-home orders and travel restrictions, may increase unhealthy lifestyles like sedentary, overuse of electronic devices, and thus increase the risk of NCDs [20]. Future studies with a longer observation period are needed to further identify the effect.

Conclusions, implications for policy, practice, and research

In summary, we provided scientific evidence of the impact of intervention during the COVID-19 epidemic on hospital visits based on this quasi-experiment study. What’s more, lessons should be taken from the intervention. Proposing suggestions for wearing masks during the epidemic period of respiratory diseases, and mitigating the impact of the COVID-19 on health care systems are important for future disease control and prevention.

Contributorship

*** designed this study and wrote the manuscript; *** and *** were in charge of the statistical analysis and interpretation of the results; *** collected and processed data; ***, ***, *** and *** conducted this study;*** and *** designed this study and made critical revisions of the manuscript.

Ethics and other permissions
This study was approved by the Institutional Review Board of the Zhejiang University School of Medicine. Informed consent was not required because anonymous and de-identified information was used for our analysis.

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**Conflict of interests**

None.

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**Data Availability**

No new data were generated or analysed in support of this review.
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Figure Legends

**Figure 1** Impact of intervention to COVID-19 on weekly total hospital visits from January 1st, 2017 to September 6th, 2020 (Grey background: post-intervention period).

**Figure 2** Weekly hospital visits for cause-specific diseases which were observed to be decreased following the intervention to COVID-19 from January 1st, 2017 to September 6th, 2020 (Grey background: post-intervention period).
Figure 3: Weekly hospital visits for cause-specific diseases which were observed to be increased following the intervention to COVID-19.
Supplementary Figure 1 Weekly hospital visits for cause-specific diseases which were observed to remain stable following the intervention to COVID-19 from January 1st, 2017 to September 6th, 2020 (Grey background: post-intervention period).
**Table 1** Description of total and cause-specific hospital visits during the pre- and post-intervention period.

| Disease classification | ICD-10 | Pre-intervention | Post-intervention |
|------------------------|--------|------------------|-------------------|
|                        | Overall visits (N, %) | Visits per week | Overall visits (N, %) | Visits per week |
| Total visits           | *      | 42,113,607 (100) | 263210            | 6,460,521 (100) | 201891        |
| Certain infectious and parasitic diseases | A00-B99 | 1,424,634 (3.38) | 8904              | 218,795 (3.39) | 6837          |
| Neoplasms              | C00-D48 | 218,993 (0.52)   | 1369              | 65,292 (1.01)  | 2040          |
| Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism | D50-D89 | 127,367 (0.30)   | 796               | 32,754 (0.51)  | 1024          |
| Endocrine, nutritional and metabolic diseases | E00-E90 | 2,089,803 (4.96) | 13061             | 456,020 (7.06) | 14251         |
| Mental and behavioral disorders | F00-F99 | 323,203 (0.77)   | 2020              | 83,648 (1.29)  | 2614          |
| Diseases of the nervous system | G00-G99 | 639,482 (1.52)   | 3997              | 154,474 (2.39) | 4827          |
| Diseases of the eye and adnexa | H00-H59 | 2,318,530 (5.51) | 14491             | 419,608 (6.49) | 13113         |
| Diseases of the ear and mastoid process | H60-H95 | 326,355 (0.77)   | 2040              | 56,999 (0.88)  | 1781          |
| Diseases of the circulatory system | I00-I99 | 5,204,902 (12.36)| 32531             | 904,133 (13.99)| 28254         |
| Diseases of the respiratory system | J00-J99 | 6,506,252 (15.45)| 40664             | 436,494 (6.76) | 13640         |
| Disease classification                                      | ICD-10 | Pre-intervention | Post-intervention |
|-----------------------------------------------------------|--------|------------------|-------------------|
|                                                           | Overall visits (N, %) | Visits per week | Overall visits (N, %) | Visits per week |
| Diseases of the digestive system                          | K00-K93 | 3,428,444 (8.14) | 21428             | 641,807 (9.93) | 20056 |
| Diseases of the skin and subcutaneous tissue              | L00-L99 | 1,704,263 (4.05) | 10652             | 322,254 (4.99) | 10070 |
| Diseases of the musculoskeletal system and connective     | M00-M99 | 2,689,785 (6.39) | 16811             | 522,245 (8.08) | 16320 |
| tissuel                                                          |         |                  |                    |                 |       |
| Diseases of the genitourinary system                      | N00-N99 | 1,951,104 (4.63) | 12194             | 385,625 (5.97) | 12051 |
| Pregnancy, childbirth and the puerperium                   | O00-O99 | 136,683 (0.32)   | 854               | 31,954 (0.49)  | 999   |
| Certain conditions originating in the perinatal period     | P00-P96 | 21,126 (0.05)    | 132               | 5,267 (0.08)   | 165   |
| Congenital malformations deformations and                 | Q00-Q99 | 22,119 (0.05)    | 138               | 6,180 (0.10)   | 193   |
| chromosomal abnormalities                                  |         |                  |                    |                 |       |
| Symptoms, signs and abnormal clinical and laboratory      | R00-R99 | 1,600,897 (3.80) | 10006             | 268,926 (4.16) | 8404  |
| findings, not elsewhere classified                         |         |                  |                    |                 |       |
| Injury, poisoning, and certain other consequences of       | S00-T98 | 2,018,005 (4.79) | 12613             | 364,358 (5.64) | 11386 |
| external causes                                           |         |                  |                    |                 |       |
| Factors influencing health status and contact with         | Z00-Z99 | 2,424,535 (5.76) | 15153             | 496,625 (7.69) | 15520 |
| health services                                           |         |                  |                    |                 |       |
| Disease classification | ICD-10 | Pre-intervention | Post-intervention |
|------------------------|--------|------------------|-------------------|
|                        | Overall visits (N, %) | Visits per week | Overall visits (N, %) | Visits per week |
| Not classified          | *      | 6,937,125 (16.47) | 43357            | 587,063 (9.09) | 18346 |

NOTES * not applicable
### Table 2 Changes in total and cause-specific hospital visits during the pre- and post-intervention period.

| Disease classification                                                                 | ICD-10     | changes (%, 95% CI) | P       |
|----------------------------------------------------------------------------------------|------------|---------------------|---------|
| Total visits                                                                           | *          | -22.60 (-27.53, -17.36) | <0.001  |
| Certain infectious and parasitic diseases                                               | A00-B99   | -29.81 (-34.01, -25.36) | 0.001   |
| Neoplasms                                                                              | C00-D48   | -14.20 (-21.23, -6.55) | 0.001   |
| Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism | D50-D89   | -7.90 (-14.65, -0.63) | 0.035   |
| Endocrine, nutritional and metabolic diseases                                          | E00-E90   | -0.10 (-7.59, +8.42)  | 0.980   |
| Mental and behavioral disorders                                                        | F00-F99   | -4.90 (-11.37, +2.04) | 0.164   |
| Diseases of the nervous system                                                         | G00-G99   | +11.17 (+3.21, +19.74) | 0.006   |
| Diseases of the eye and adnexa                                                         | H00-H59   | -18.31 (-24.99, -11.06) | <0.001  |
| Diseases of the ear and mastoid process                                               | H60-H95   | -17.29 (-22.75, -11.46) | <0.001  |
| Diseases of the circulatory system                                                     | I00-I99   | -1.36 (-9.53, +7.52)  | 0.756   |
| Diseases of the respiratory system                                                     | J00-J99   | -62.25 (-65.62, -58.60) | <0.001  |
| Diseases of the digestive system                                                       | K00-K93   | +1.58 (-5.32, +8.97)  | 0.662   |
| Diseases of the skin and subcutaneous tissue                                          | L00-L99   | -7.21 (-12.76, -1.33) | 0.018   |
| Diseases of the musculoskeletal system and connective tissue                          | M00-M99   | -10.01 (-15.84, -3.80) | 0.002   |
| Diseases of the genitourinary system                                                   | N00-N99   | -6.15 (-12.35, +0.47) | 0.070   |
| Pregnancy, childbirth and the puerperium                                               | O00-O99   | +27.01 (+17.89, +36.85) | <0.001  |
| Category                                                                 | Code  | Change (95% CI) | p-value |
|------------------------------------------------------------------------|-------|-----------------|---------|
| Certain conditions originating in the perinatal period                | P00-P96 | +45.05 (+30.24, +61.56) | <0.001  |
| Congenital malformations deformations and chromosomal abnormalities    | Q00-Q99 | +35.50 (+21.24, +51.45) | <0.001  |
| Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified | R00-R99 | -18.39 (-23.27, -13.22) | <0.001  |
| Injury, poisoning, and certain other consequences of external causes   | S00-T98 | -0.61 (-5.98, +5.05) | 0.828   |
| Factors influencing health status and contact with health services     | Z00-Z99 | -0.98 (-9.88, +8.79) | 0.839   |

NOTES * not applicable