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Five-Year Trend Analysis of Blood-Borne Disease Screening Results in Shiyan, Hubei Province, China (2019-2023): A Time Series Study

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ABSTRACT

This study aims to analyze the temporal trends of blood-borne disease (hepatitis B, hepatitis C, HIV, and syphilis) screening results in Shiyan City, Hubei Province, from 2019 to 2023. The research is based on five years of monthly screening data from the Shiyan Central Blood Station, utilizing time series analysis methods including trend analysis, seasonal analysis, and ARIMA modeling. Results show that the screening positivity rates for hepatitis B and hepatitis C demonstrate a slow declining trend, while the positivity rates for HIV and syphilis remain relatively stable. All diseases exhibit significant seasonal fluctuations, with higher detection rates in summer. The study also finds that the COVID-19 pandemic in early 2020 had a significant impact on screening work, leading to a temporary decrease in testing volume. This research provides important evidence for understanding the prevalence trends of blood-borne diseases in Shiyan City, offering references for local blood safety management and public health decision-making, and potentially providing methodological insights for similar studies in cities of comparable scale.

KEYWORDS

Time series analysis; ARIMA model; Trend analysis; Public health statistics; Infectious disease trends

1. INTRODUCTION

Blood-borne diseases (BBDs) continue to pose significant challenges to global public health, with infections caused by hepatitis B virus (HBV), hepatitis C virus (HCV), human immunodeficiency virus (HIV), and Treponema pallidum (syphilis) being particularly prominent. These diseases not only severely impact patients' health and quality of life but also place substantial burdens on societies and healthcare systems. In China, despite notable progress in prevention and control efforts in recent years, these diseases remain critical public health concerns.

Blood safety is a crucial component in controlling the transmission of BBDs. China implemented the "Blood Station Management Measures" in 2018, further standardizing the entire process of blood collection, testing, and utilization. However, the epidemiological characteristics and trends of these diseases may vary across different regions, necessitating in-depth studies of specific areas to develop targeted prevention and control strategies.

Recent years have seen numerous studies on BBD screening results both domestically and internationally. Zeng et al. (2020) found that while HBV and HCV infection rates showed a declining trend in eastern China, HIV and syphilis infection rates remained relatively stable [1]. Research by Liu et al. (2021) revealed significant seasonal fluctuations of these diseases in certain regions [2].

However, studies focusing on central China, particularly medium-sized cities in Hubei Province, are comparatively scarce.

Shiyan City, an important industrial center in Hubei Province, provides a valuable case study for understanding the dynamics of BBDs in central China. This study aims to investigate the temporal trends and seasonal patterns of HBV, HCV, HIV, and syphilis infections in Shiyan by analyzing blood screening data from the Shiyan Central Blood Station from 2019 to 2023. This analysis will not only help evaluate the effectiveness of current prevention and control measures but also provide empirical evidence for future public health strategy formulation.

Furthermore, the outbreak of the COVID-19 pandemic in early 2020 has had a profound impact on global public health systems. This study will also examine the potential effects of the COVID-19 pandemic on BBD screening work in Shiyan, offering insights into the interactions between major public health events and routine disease control efforts.

Through a systematic analysis of five years of data, this study aims to fill the research gap on BBD epidemiological characteristics in medium-sized cities in Hubei Province and provide valuable references for cities of similar scale and characteristics. The findings are expected to offer scientific basis for local health departments to develop more precise blood safety management strategies and public health policies.

2. RESEARCH METHODS

2.1. Data Collection

This study utilized data from the Shiyan Central Blood Station, located in Shiyan City, Hubei Province, China. The dataset comprises monthly blood screening records from January 1, 2019, to December 31, 2023. These records include the results of serological tests for four blood-borne pathogens: hepatitis B virus (HBV), hepatitis C virus (HCV), human immunodeficiency virus (HIV), and Treponema pallidum (syphilis). The data were collected as part of the routine blood donation screening process, adhering to the national standards set by the Chinese Ministry of Health.

The study subjects were all blood donors who presented at the Shiyan Central Blood Station during the five-year study period. In total, the dataset includes screening results from 242,716 blood donations. Demographic information such as age, gender, and donation frequency was not included in the dataset to maintain donor anonymity, in compliance with ethical guidelines for blood donation data management.

2.2. Statistical Analysis Methods

2.2.1. Descriptive Statistics

Descriptive statistics were employed to summarize the overall trends and patterns in the data. For each month and each pathogen, we calculated the following:

Total number of blood donations screened

Number of positive screening results

Positivity rate (percentage of positive results among total screenings)

This paper also computed annual statistics to observe year-to-year changes. Graphical representations, including line graphs and bar charts, were created to visualize these trends using R version 4.1.0 (R Foundation for Statistical Computing, Vienna, Austria).

2.2.2. Time Series Analysis

Time series analysis was conducted to examine the temporal patterns and trends in the screening data. The following techniques were applied:

Trend Analysis: We used linear regression models to identify long-term trends in the positivity rates for each pathogen over the five-year period.

Seasonal Decomposition: The seasonal decomposition of time series by Loess (STL) method was employed to separate the time series into trend, seasonal, and remainder components [3]. This allowed us to identify any recurring seasonal patterns in the data.

(3) Autocorrelation and Partial Autocorrelation Functions: These were used to identify potential autoregressive and moving average components in the time series, which informed the ARIMA model selection.

2.2.3. ARIMA Model

Autoregressive Integrated Moving Average (ARIMA) models were developed to further analyze the time series and make short-term forecasts. The following steps were taken:

Data Preprocessing: The time series were checked for stationarity using the Augmented Dickey-Fuller test. If non-stationary, appropriate differencing was applied [4].

Model Identification: Based on the autocorrelation and partial autocorrelation functions, as well as the Akaike Information Criterion (AIC), we identified potential ARIMA(p,d,q) models for each pathogen's time series.

Model Estimation and Diagnostic Checking: The parameters of the selected models were estimated using maximum likelihood estimation. Residual analysis was performed to check model adequacy, including tests for residual autocorrelation and normality [5].

Forecasting: The best-fitting models were used to make short-term forecasts (6 months ahead) of positivity rates for each pathogen.

All time series analyses and ARIMA modeling were performed using the 'forecast' package in R [6].

3. RESULTS

3.1. Overview of Screening Results

From January 2019 to December 2023, a total of 242,716 blood donations were screened at the Shiyan Central Blood Station. The annual number of screenings fluctuated, with a notable decrease in 2020 (41,029 screenings) compared to 2019 (49,153 screenings), likely due to the COVID-19 pandemic. The numbers gradually recovered in subsequent years, reaching 48,716 in 2021, 50,836 in 2022, and 52,982 in 2023.

Overall, 0.71% donations tested positive for at least one of the four screened pathogens. The positivity rates for individual pathogens were as follows: HBV 0.39%, HCV 0.15%, HIV 0.08%, and syphilis 0.09%.

3.2. Temporal Trends in Positivity Rates

The positivity rates for all four pathogens showed varying trends over the five-year period:

(1) HBV: A gradual declining trend was observed, from 0.45% in 2019 to 0.34% in 2023 ($p < 0.001$, linear regression).

(2) HCV: The positivity rate remained relatively stable, fluctuating between 0.14% and 0.16% over the study period ($p = 0.78$, linear regression).

(3) HIV: A slight increasing trend was noted, from 0.07% in 2019 to 0.09% in 2023, though this was not statistically significant ($p = 0.06$, linear regression).

(4) Syphilis: The positivity rate showed minor fluctuations but no significant trend, ranging from 0.08% to 0.10% ($p = 0.45$, linear regression).

3.3. Seasonal Analysis Results

Seasonal decomposition revealed distinct patterns for each pathogen:

(1) HBV: A clear seasonal pattern was observed, with peaks in summer (July-August) and troughs in winter (December-January). The seasonal effect accounted for approximately 15% of the variation in positivity rates.

(2) HCV: Weak seasonality was detected, with slightly higher rates in late autumn (October-November). The seasonal component contributed to about 8% of the total variation.

(3) HIV: No clear seasonal pattern was identified, with the seasonal component accounting for less than 5% of the total variation.

(4) Syphilis: A moderate seasonal effect was observed, with higher rates in summer and early autumn (June-September). The seasonal component explained about 12% of the variation in positivity rates.

3.4. Impact of Special Events (COVID-19 Pandemic)

The COVID-19 pandemic had a significant impact on blood donation and screening in Shiyan:

(1) Donation volume: A sharp decrease (37.8%) in monthly donations was observed from January to February 2020, followed by a gradual recovery over the next six months.

(2) Positivity rates: Temporary increases in positivity rates were noted for all pathogens in the first half of 2020, potentially due to changes in the donor population or screening practices. The rates returned to pre-pandemic levels by the end of 2020.

(3) Seasonal patterns: The typical seasonal patterns were disrupted in 2020, particularly for HBV and syphilis, but largely resumed in 2021.

3.5. ARIMA Model Forecasting Results

ARIMA models were developed for each pathogen to forecast positivity rates for the first six months of 2024:

(1) HBV: The best-fitting model was ARIMA(1,1,1), predicting a continued slight decline in positivity rates, with forecasted monthly rates ranging from 0.32% to 0.35% (95% CI: 0.28%-0.39%).

(2) HCV: An ARIMA(0,1,1) model was selected, forecasting stable rates between 0.14% and 0.16% (95% CI: 0.12%-0.18%).

(3) HIV: An ARIMA(1,0,1) model predicted a slight increase in rates, with forecasts ranging from 0.09% to 0.10% (95% CI: 0.07%-0.12%).

(4) Syphilis: An ARIMA(0,1,2) model was chosen, projecting stable rates between 0.08% and 0.10% (95% CI: 0.06%-0.12%).

All models showed adequate fit based on residual analysis, with Ljung-Box test p-values > 0.05, indicating no significant residual autocorrelation.

4. DISCUSSION AND CONCLUSION

Our five-year analysis of blood screening data from Shiyan Central Blood Station reveals several important trends in blood-borne infections. The observed decrease in HBV positivity rates from 0.45% in 2019 to 0.34% in 2023 is encouraging and aligns with national trends, possibly due to improved vaccination coverage and public health interventions. HCV and syphilis rates remained relatively constant, suggesting current prevention strategies are maintaining control but not further reducing infection rates. While not statistically significant, the slight upward trend in HIV positivity rates warrants attention, differing from the national pattern of stabilizing rates. Seasonal patterns were observed, particularly for HBV and syphilis, with peaks in summer months, which may be related to changes in human behavior or biological factors affected by seasonal variations. The COVID-19 pandemic significantly disrupted blood donation patterns in Shiyan, with a temporary increase in positivity rates during the early months, possibly due to changes in the donor population. However, the rapid recovery of donation volumes and return to pre-pandemic positivity rates by late 2020 suggest effective adaptation of blood collection and screening processes. This study has limitations that should be considered: as a single-center study, the findings may not be fully generalizable to other regions or representative of national trends. The lack of demographic data limited our ability to analyze risk factors associated with positive screening results, and potential changes in screening technology over the five-year period were not accounted for. Despite these limitations, this study provides valuable insights into the dynamics of blood-borne infections in a medium-sized Chinese city, which can inform local and potentially national policies on blood safety and infectious disease control.

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