



Case Report

A Long-Term Impact Study of Bacterial Outbreak Using Control Chart-Risk Assessment Combination

Mostafa Essam Ahmed Eissa

Independent Ph.D. Researcher and Candidate, Department of Microbiology and Immunology, Cairo University, Cairo, Egypt

Received: 10 May 2019 / Accepted: 11 June 2019

Abstract

Outbreaks are a major health problem that requires immediate and rigorous corrective actions based on accurate data gathering. A correct interpretation of a long-term record of an epidemiological disease is crucial in deriving useful information and lessons-to-learn in order to understand the pattern and nature of outbreaks. An internet-based record extraction was conducted for the National Outbreak Reporting System (NORS) website database which is a platform developed by the Centers for Disease Control and Prevention (CDC). Data were filtered and processed using statistical process control (SPC) software that is available commercially. The selected focus group of the current study was bacterial outbreak incidents in the USA during the 20 years period. Data were interpreted using Laney attribute control charts to overcome for over or under-dispersion of data which may lead to false alarm detection. Control charts showed the pattern of the selected cases of the bacterial outbreak trend in the country. These process-behavior charts could define outbreak parameters such as mean values of ill cases per outbreak, upper control limit (UCL), number of outbreaks during a specific fixed time, number of excursions in the number of ill populations per outbreak (out-of-control). A quantitative risk analysis could be derived from the trending charts. Accordingly, The most influential bacterial outbreaks that contributed by about 88 % of the illness cases in the studied group were *Clostridium* spp., *Shigella* spp. and *Escherichia coli*, Trending charts can be used as a mean to assess and compare the potential risks of outbreaks from different bacteria.

Keywords: NORS, SPC, Laney attribute control charts, UCL, Out-of-control, CDC

Corresponding Author: Mostafa Essam Ahmed Eissa, Independent Ph.D. Researcher and Candidate, Department of Microbiology and Immunology, Cairo University, Cairo, Egypt. E-mail: mostafaessameissa@yahoo.com

DOI: 10.5455/ww.48101

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Introduction

Epidemiological outbreaks have been a great issue of concern that impacts human health and life, in addition to the economic consequences.^{1,2} Developed countries have established an effective and rigorous monitoring system for outbreaks. Thus, comprehensive records could provide valuable data about the pattern of outbreaks to derive useful lessons for future control and prevention.³ Special attention is brought to the bacterial outbreaks where devastating consequences on the population exposed to harmful microorganisms or their toxins have been reported by several researchers.⁴⁻⁶

Bacterial epidemics and outbreaks were responsible for massive casualties and mortalities during the human history of life on earth that harvested millions of lives such as Plague and Cholera. Due to the above and previous challenges, the current work examines the use of control charts as a tool to study the selected group of the bacterial outbreaks and assess their relative risk based on the outcome parameters from these trending charts. The present case study will show the pattern of each type of the outbreak and assesses the health hazard quantitatively as an objective tool for prioritization and decision making to set measures of epidemiological control of the disease.

Case Report

Epidemiological monitoring information was obtained from the database of the National Outbreak Reporting System (NORS). NORS is an Internet-based site that was functioning from 2009 by the Centers for Disease Control and Prevention (CDC). Cases of sickness for each outbreak were used from "National Outbreak Public Data Tool" where records were stratified, and bacterial outbreaks were separated for each common type and filtered. Records were segregated into individually selected food types then each data set was processed and presented as control charts using commercial statistical process control (SPC) software Minitab® V17.1.0. Laney modification was used for attribute control charts to correct data dispersion and avoid false alarms.^{7,8} The magnitude of dispersion is indicated by Sigma Z value in the process-behavior chart. Accordingly, Figure 1 is produced showing the mean value of ill individuals, upper control limit (UCL) of the number of cases threshold, number of outbreaks for 20 years (1998 to 2017), the number and the magnitude of the out-of-control cases for each type of the bacterial outbreak in the USA.

Figure 2 is showing a Pareto chart which demonstrates major contributor's bacterial genus to the affected population illness using a quantitative modification of Failure Mode and Effects Analysis (FMEA). The quantitative risk probability number (qRPN) is the product of multiplication of the three factors in Figure 1 i.e. Severity (S) x Frequency (F) x Detectability (D). S factor is the average value of illnesses recorded for a specific outbreak during the recording and monitoring period. On the other hand, F value is the rate of occurrence of the outbreak per specific period (i.e. 1998 to 2017). Finally, D figure was taken from the upper threshold value of the trending charts for 20 years. The multiplication process would amplify the difference between different groups to facilitate the comparison between the observations.

Discussion

The monitored bacterial outbreaks are usually found to be mediated through food a vehicle which indicates a crucial problem with food safety and control. This challenge has been reported previously by some investigators.⁹ Outbreaks involving *Pseudomonas* spp. and *Yersinia* spp. as etiological agents are the least common and occurred with very low frequency during the study period. In contrast, *Clostridium* spp. and *Shigella* spp. are the most frequently occurring outbreaks from 1998 to 2017. The upper thresholds (expressed as the ill number of cases per an outbreak) for the bacterial outbreaks before a true excursion would be considered could be arranged in the following descending order: *Clostridium*

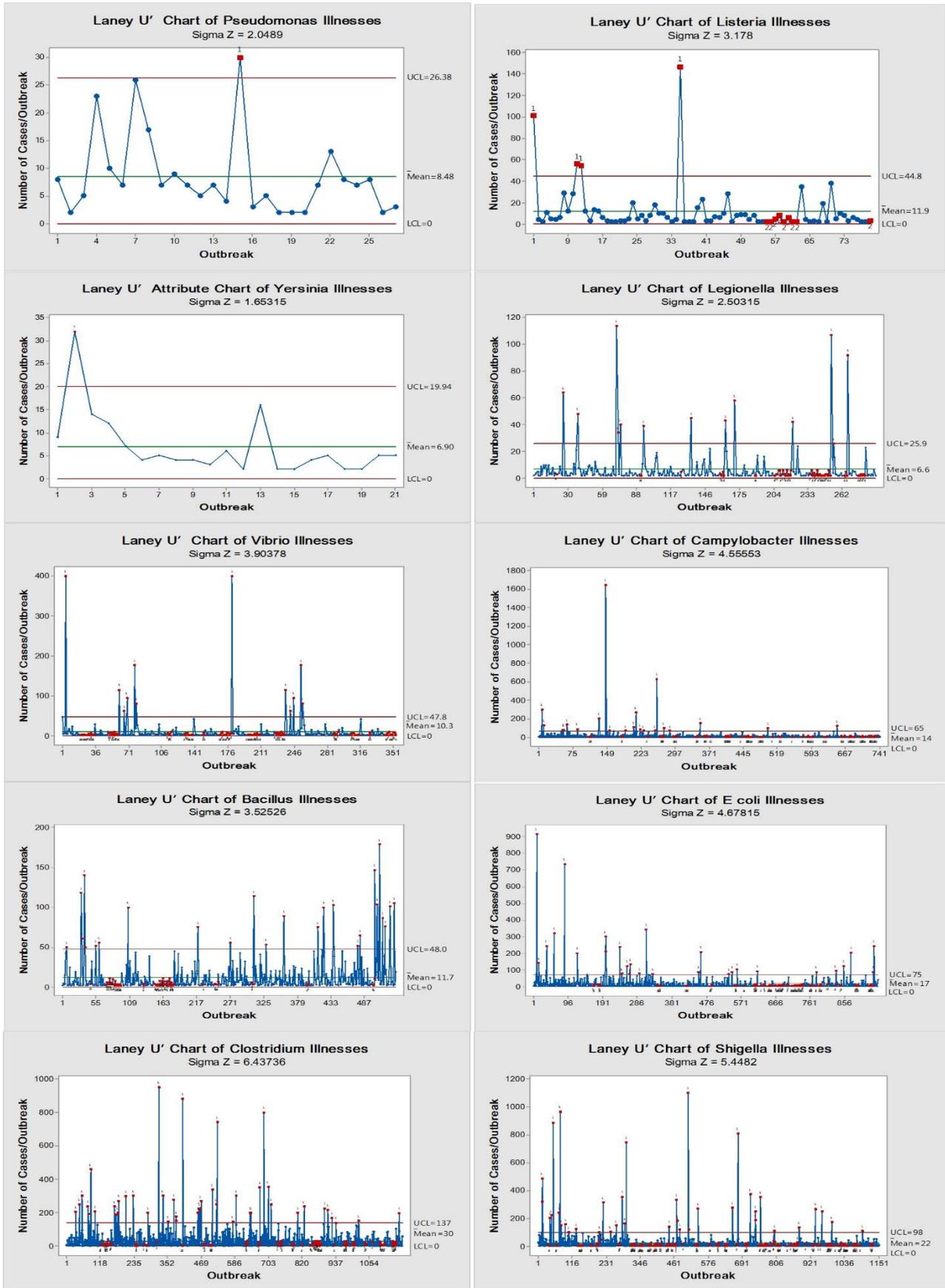


Figure 1. Laney attribute control charts for outbreaks involving common bacterial species for 20 years.

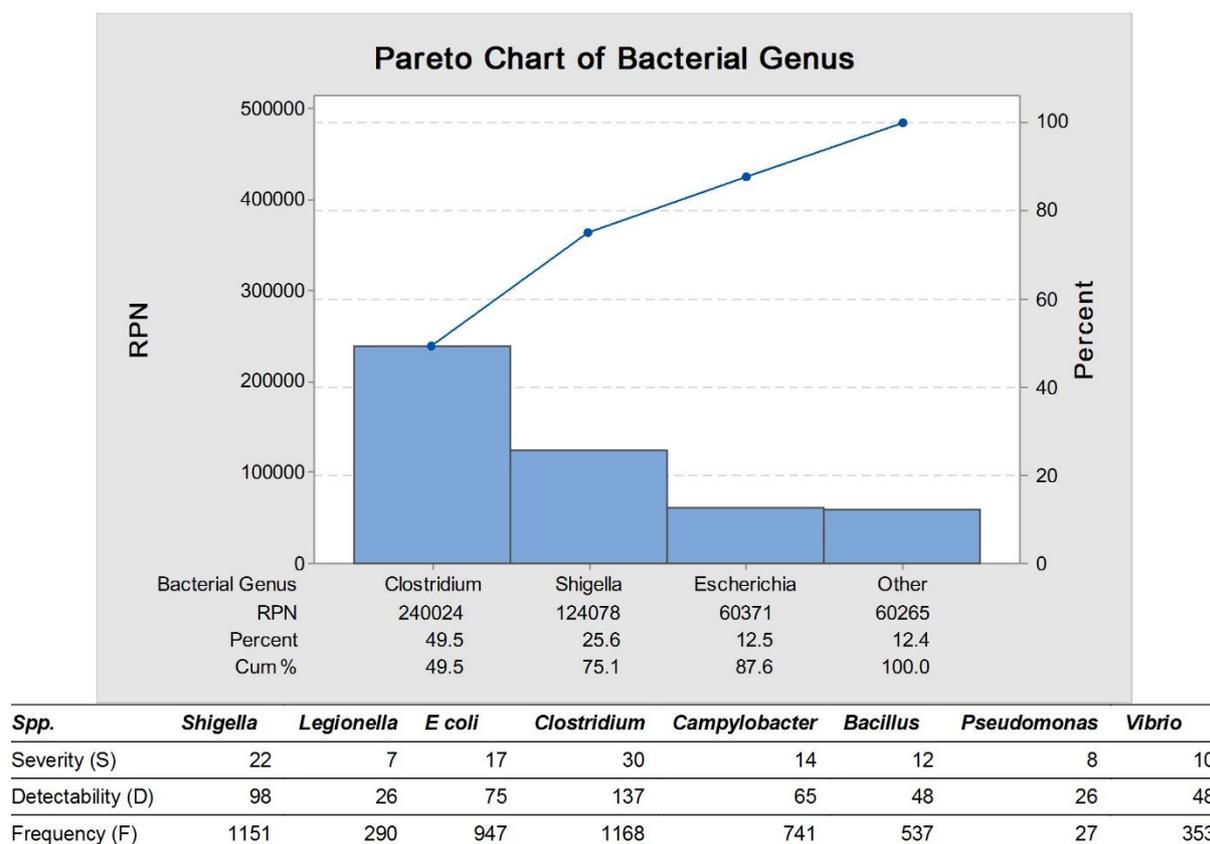


Figure 2. Pareto plot diagram showing major bacterial genus contributing to the health risk.

spp. (137), Shigella spp. (98), Escherichia coli (75), Campylobacter spp. (65), Bacillus spp. (48), Vibrio spp. (48), Listeria spp. (45), Pseudomonas spp. (26), Legionella spp. (26) and Yersinia spp. (20). A Control chart is an indispensable tool in the monitoring and the visual assessment of the inspected characteristic.¹⁰ Moreover, quantitative parameters could be deduced for each Shewhart chart constructed for a specific outbreak.

The principle of FMEA analysis could be applied in the present case with modification to determine the hazard numerically in a quantitative manner to suite the existing case study.¹¹ This is useful in decision making and focusing on corrective and preventive actions for the main etiological sources of the outbreaks.^{12,13} Similar results to what was concluded in this study were observed for bacterial outbreaks especially through food sources as a vehicle for disease transmission.^{14,15} Quantitative FMEA showed that Clostridium spp. risk accounted for about 50 % of illness cases, followed by Shigella spp. and Escherichia coli. In general, outbreaks are characterized by their persistent nature of emergence from time-to-time with different magnitudes which are considered limited in the developed countries if compared with those in the developing nations where the regulatory controls, sanitization procedures and the perception of the hygiene measures are still suffering from great deficiencies. These problems may result in catastrophic events of outbreaks with great health and financial losses for countries that already are economically poor.

Conclusion

SPC tools are valuable in the monitoring of the outbreaks and could provide a mean to assess the health risk encountered from bacterial epidemiological outbreaks. Simplified risk analysis based on FMEA could determine the major contributor bacterial types for outbreak illness population which is (in this case) could be attributed by more than 85 % to Clostridium, Shigella and Escherichia spp. based on the trend analysis in the country for 20 years period of observation and recording.

The derived risk assessment in this study is simple and decision-making supportive for the focus on the major etiological agents for the outbreaks as a directive tool for the establishment of appropriate containment and corrective procedures.

Author contributions

MEAE conceived of the study and participated in its design and coordination as well as helped to draft the manuscript; also read and approved the final manuscript.

Funding

There was no funding received for this paper.

Conflict of interest

All authors declare that they have no conflict of interest.

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