G-control Charts for Contamination Rates of Blood Cultures in a University Hospital

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ABSTRACT

Objective: To determine blood culture contamination rates, and display with a *g*-chart.

Materials and Methods: A retrospective cohort study was conducted. The medical records of patients, from whom blood cultures were obtained in a university hospital, during January and December, 2019 were retrieved and reviewed for contamination. The Centers for Disease Control and Prevention (CDC) criteria were used to classify the blood culture results. The contamination rates were illustrated with a *g*-chart.

Results: We identified 331 false-positive blood cultures, among 32,961 cultured specimens; yielding a contamination rate of 1.0% (95% CI = 0.9% – 1.1%). The highest contamination events occurred in the emergency department (49.2%), pediatric ICU (5.2%) and neonatal ICU (4.8%), respectively. The most common contaminated commensal bacterial genus were coagulase -negative *Staphylococci* (67.1%), *Bacillus* spp. (10.2%) and *Corynebacterium* spp. (7.6%). The *g*-charts could identify 14 abnormal variations, in 41 locations.

Conclusion: The contamination rates found were within ranges of other reports. *G*-charts are simple to construct, easy to interpret and sensitive for detection of real time epidemics.

Keywords: Hemoculture; blood culture; contamination; rate; geometric; SPC chart (Siriraj Med J 2021; 73: 406-412)

INTRODUCTION

Blood cultures play an important role in the management of bloodstream infections, due to it is a critical tool detecting the dangerous presence of living organisms in the blood stream. However, the merits of blood culture results are jeopardized by false positives, resulting from contamination during the taking or processing of blood specimens. Blood culture contamination represents an ongoing source of frustration for clinicians and microbiologists alike. Ambiguous culture results often lead to diagnostic uncertainty in clinical management and are associated with increased health care costs due to unnecessary treatment and testing.[1] There are several steps in the process of taking blood cultures that may influence the contamination rate. Blood culture contamination has been attributed to the transference of organisms from the patient's skin, the immediate environment of the patients, supplies used to obtain or transfer the blood samples or from the hands of the health care worker performing the procedure.[2-3]

In this era of strains on the resources and rising cost of healthcare, it becomes increasingly apparent that decisions must be made on facts, not just opinions. Consequently, data must be gathered and analyzed. This is where statistical process control (SPC) comes in. For over decades, the healthcare setting has benefited from the tools of SPC that have helped guide the decision-making process.[4-5]

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Received 18 September 2020 Revised 1 April 2021 Accepted 2 April 2021
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http://dx.doi.org/10.33192/Smj.2021.54

Control chart is the main tool in SPC and usually used for monitoring and improving the ongoing process. Geometric SPC chart (*g*-chart) is based on the geometric distribution and was designed to monitor rare events.

Primary baseline data is an essential part of any quality improvement project. Hence, the primary intention of this study was to determine blood culture contamination rates, and display with a *g*-chart. To document the rates, and variations of blood culture contaminations needed for a blood culture quality improvement project.

MATERIALS AND METHODS

Setting

The study was conducted in Songklanagarind Hospital, a tertiary care, medical school, and training hospital in Southern Thailand. In our hospital, clinical blood culture samples are usually collected at the bedside, from two separated specimens; taken from different venipuncture sites.

Studied samples

Blood culture specimens taken from patients admitted to the hospital, from the 1st of January to the 31st of December, 2019.

Blood sample collection

Prior to venipuncture, the skin was disinfected with a combination of 2% chlorhexidine gluconate and 70% alcohol, for 30 seconds, then allowed to dry, except that taken from infants <2 months, in which 70% alcohol would be used instead. After antisepsis, the veins would not be touch, without use of sterile gloves. Then the vein is pierced with a needle, and drawn into a syringe. Samples were subsequently inoculated into blood culture bottles without change of needles. Blood culture collection kits are not used in this process.

Specimen Processing

Blood samples were obtained in media bottles, and kept at room temperature before being transferred, as soon as possible, to the microbiology laboratory for processing (within 2 hours). Blood culture specimens were incubated in automated instruments for 5 days, or until the automate alarm for positive blood culture.

The automated blood culture system used in the hospital is BD BACTEC FX (BACTEC) by Becton Dickson & Co., sparks, MD. It is used to process blood cultures with isolates identified using MALDI-TOF and biochemical methods, according to standard practices.

Microbiology lab identification

Once blood cultures become positive for growth, either by manual subculture techniques (blood agar, chocolate agar, and MacConkey agar) or signaling from automated systems, a Gram stain is performed. A positive Gram stain result is regarded as a critical value, and the ordering clinician, or another responsible member of the healthcare team providing care to the patient is immediately informed. At this point, subcultures are performed and these allow identification and, if indicated, susceptibility testing is then performed; typically over the next 24-48 hrs. Complete organism identification and organism-specific susceptibility testing is performed on all positive blood culture specimens.

Definitions of blood cultures

1. Positive Blood cultures: Any blood cultures which microorganisms are found.
2. Blood Stream Infection: Positive Blood cultures which the microorganisms are not included in CDC common commensal lists[6] or two blood specimens found the same microorganisms.
3. Secondary Blood Stream Infection: One or more positive blood cultures which the microorganisms are included in CDC common commensal lists6 and also found the same microorganisms at another site of the body.
4. Contaminated Blood cultures: One positive blood culture which the microorganisms are included in CDC common commensal lists[6] with no more than one matching organism identified in 2 separated blood specimens and No primary infection source of the organism identified Contaminated blood culture

Studied variables

The variables in this study include blood sample collecting date, age and gender of patients, wards that request blood culture and results of the blood cultures.

Statistical analysis

Continuous data were described in terms of arithmetic or geometric mean, according to the types of data distribution. Discrete data were presented as percentage. Contamination rates were calculated by dividing the number of contaminated specimens with the total number of cultured specimens. Contamination rates were reported in terms of percentage. The dispersion of data was represented by variance or 95% confidence interval (95% CI). The 95% CI of proportion were estimated based on exact binomial statistics.

Construction of the *g*-charts were done by line graph plotting the numbers of non-contaminated specimens between pairs of contaminated specimens (NBP), in axis *y* against the consecutive contaminated specimen numbers (CSN) in axis *x*. The *y*-axis is displayed in log scale base 2. The chart then starts with the second CSN, and the NBP between the first and the second CSN.[7-8]

We used median of total NBP to define the center line (CL), and used confidence intervals to define control limits of the chart. The confidence intervals were calculated using equations proposed by Yang Z et al.[9] The equation for lower limit is $ln(1 - \alpha/2)/ln(q)$ and the equation for upper limit is $ln(\alpha/2)/ln(q)-1$,where α is the cumulative probability and q is the probability of a non-contaminated specimens.[7]

Definitions of the *g*-chart; lower and upper control limits with calculation formula

Chart limits

1. Lower control limit (LCL): Lower bound of 95%CI and formula is $ln(0.975)/ln(q)$

2. Lower warning limit (LWL): Lower bound of 80%CI and formula is $ln(0.9)/ln(q)$

3. Upper warning limit (UWL): Lower bound of 80%CI and formula is $ln(0.1)/ln(q)-1$

4. Upper control limit (UCL): Lower bound of 95%CI and formula is $ln(0.025)/ln(q)-1$

ln = Natural logarithm or $\log_e$

q = Probability of non-contaminated specimen

The outbreak of blood culture contamination can be diagnosed by any of the following rules; 1) there is one point of the graph that fell under LCL, 2) there are two successive points falling under LWL 3) there are five successive points under CL, and 4) there are six successive points decreasing.

Ethics in research

The study protocol was approved by the Ethics Committees of the Faculty of Medicine, Prince of Songkla University (EC: 62-451-9-1). Because of the observational nature of the study, written informed consent was not required.

RESULTS

Characteristics of studied samples

The study included 32,961 blood culture specimens, from 8,841 hospital patients. The characteristics of the patients are shown in Table 1.

Blood culture results

Using the Center of Disease Control and Prevention (CDC) criteria[6], we could identify 331 (1.0%) contaminated blood specimens among 32,961 of the total blood specimens requested (Fig 1). The Pareto diagram of the number of contamination is illustrated in Fig 2. The contaminated micro-organisms are listed in the appendix.

TABLE 1. Demographic data of the patient, for whom blood culture specimens were taken.

Characteristics		95%CI
Age (year)	Mean = 50.53	49.95 - 51.11
Gender (%)		
Male	51.75	50.71 - 52.79
Female	48.25	47.21 - 49.29
Service (%)		
Emergency	31.22	30.72 - 31.72
Medicine	25.93	25.45 - 26.40
Surgery	18.05	17.64 - 18.47
Pediatric	13.58	13.21 - 13.95
Obstetric & Gynecology	4.04	3.83 - 4.26
Others	7.18	6.90 - 7.45

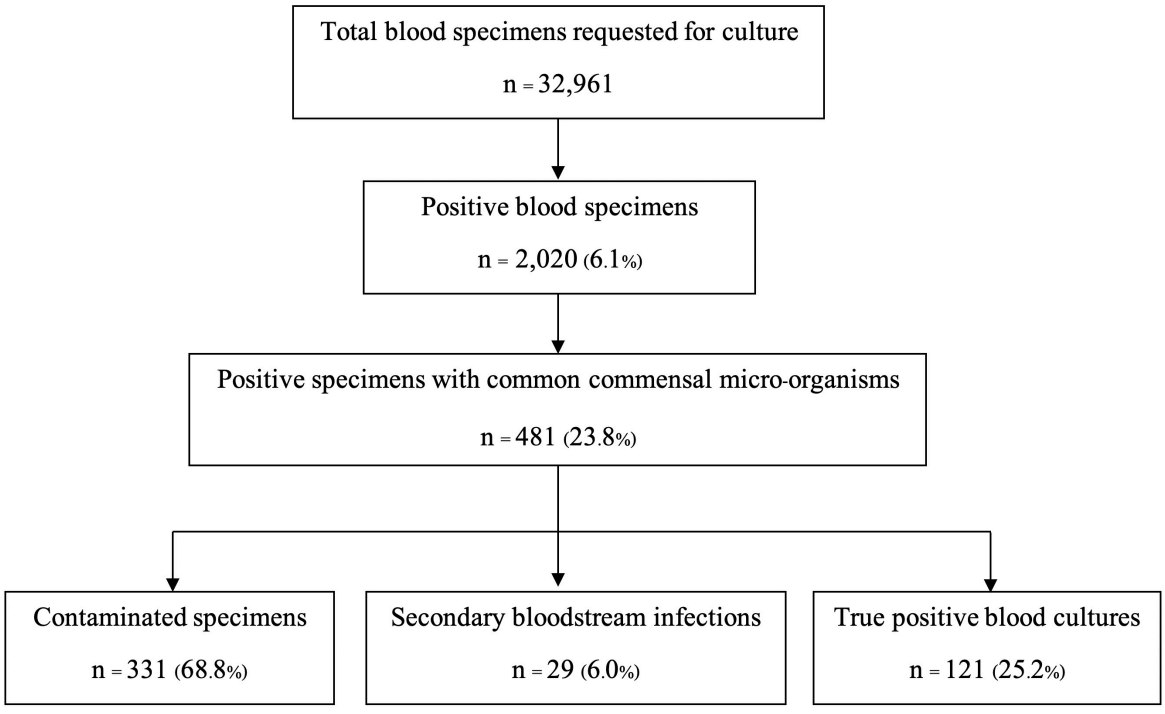

Fig 1. Blood culture results for the year 2019.

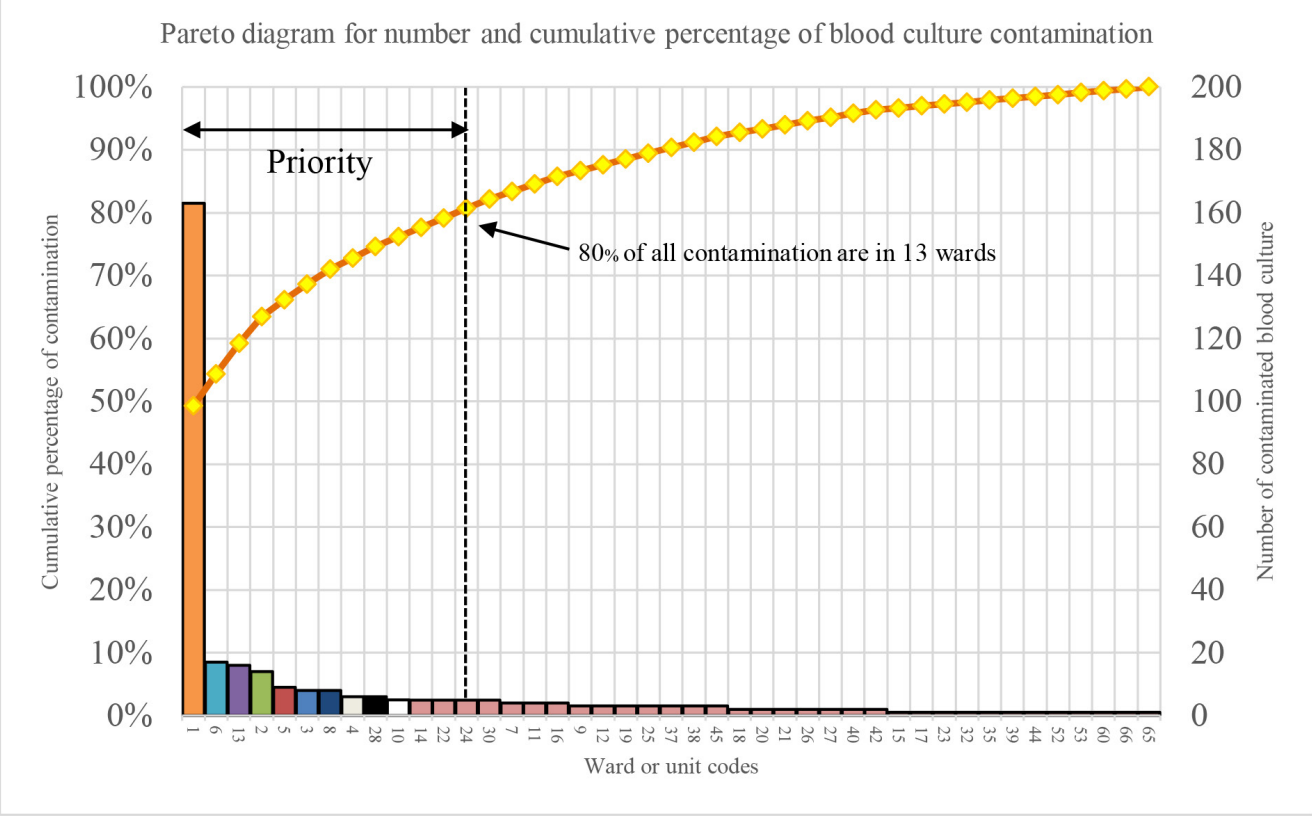

Fig 2. Pareto diagram for the number of contaminated blood culture specimens (presented with diagram) and corresponding cumulative percentage of contamination (presented with line diagram)

Descriptive data of number between contamination

The average as well as variance of numbers between contaminated blood specimens was 98 and 9,127, respectively. The median was 71. The histogram is demonstrated in Fig 3.

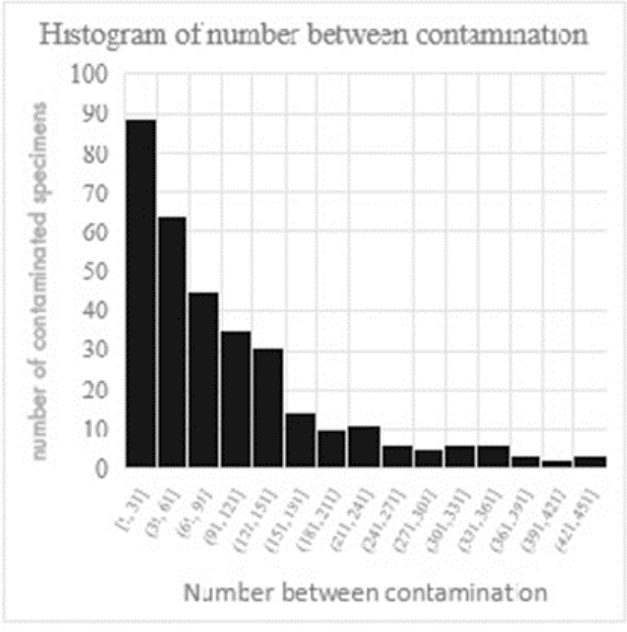

Fig 3. Histogram of the number between contaminations.

g-Control chart

The *g*-Chart of blood culture contamination, in PSU hospital for the year 2019, is illustrated in Fig 4.

Outbreak of blood culture contamination

Outbreak of blood culture contamination in Songklanagarind Hospital is shown in Table 2. We could identify 14 outbreaks in the year 2019. The average run length (average of number between outbreaks) was 19.

DISCUSSION

The study design of this research was a cross-sectional descriptive analysis, which can only study a point in time, and lacks the ability to identify the cause-effect relationship. Therefore, the results can only represent the magnitude of the problem.

Some microorganisms such as Burkholderia pickettii[10] are not enrolled in the common commensal organism's list of the CDC[6]; nonetheless, microorganisms can be causative agents for blood culture contamination. Therefore, this may be the reason for the occurrence of false negative, in the other words, the contamination rate may be possibly lower than the actual result.

Although, Songklanagarind Hospital has no phlebotomy team available the blood sample collection method is practiced via standard protocol.

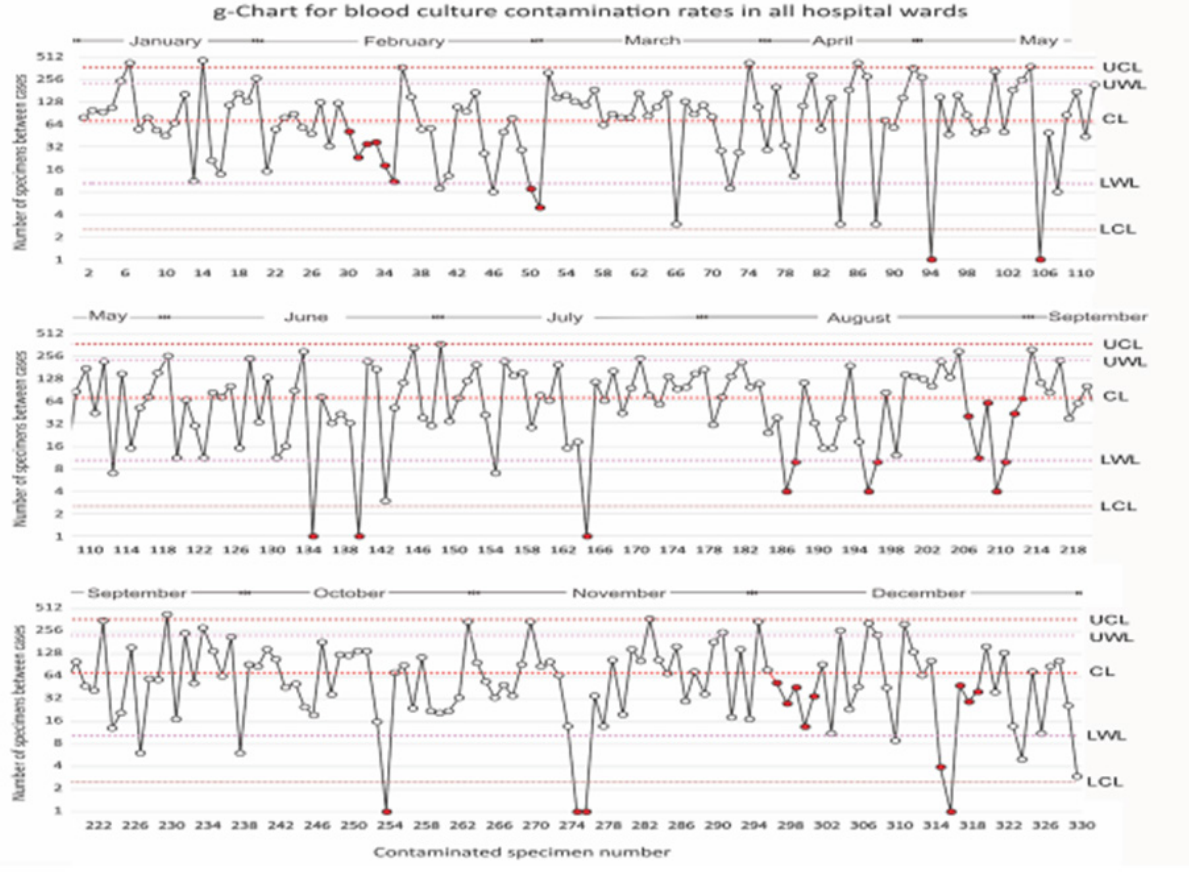

Fig 4. *g*-Chart of blood culture contamination in Songklanagarind Hospital for the year 2019.

TABLE 2. Outbreak of blood culture contamination in Songklanagarind Hospital.

Ward	Number	Criteria	Date of outbreak	
			Month	Day
All wards	1	Five points under	February	8-9
	2	Two points under		23-24
	3	One point under	May	1
	4	One point under		20
	5	One point under	June	16
	6	One point under		18
	7	One point under	July	17
	8	Two points under	August	10
	9	Two points under		15
	10	Five points under		28-30
	11	One point under	October	17
	12	Five points under	November	5-7
	13	Five points under	December	2-3
	14	Five points under		22-23
	Average run length = 19 (95%CI = 13-25)			

The results show that there is a huge difference between contamination in the Emergency Department and other services. It has been suggested that urgent care, lack of ongoing training, workload and nature of present patients may contribute to this. From the literature reviews show that Zahra Hashemizadeh had the highest contamination rate (8.47%) in Neonatal Care Units in Shiraz, Southwest-Central Iran.[11] In contrast, Chang CJ, et al. and Washer LL had the lowest contamination rate (0.2%) in discharged patients from Emergency Department, National Cheng Kung University Hospital, Taiwan, and patients using povidone-iodine and iodine as antiseptics in University of Michigan Health System respectively.[12-13] The contamination rate in a single Emergency Department at a university-affiliated, tertiary care adult hospital in the United States was maintained below 3% during each biweekly interval throughout the intervention period in the study of Self HW et al.[14] They developed the sterile blood culture intervention to convert blood culture collection from a clean to a sterile procedure.

More than 50 % of contaminated microorganism are coagulase-negative staphylococci including *Stahylococcus epidermidis* (37.18%), *Staphylococcus hominis* (8.93%), *Staphylococcus capitis* (7.49%).

The Pareto chart is one of the seven basic tools of quality control. It is a type of chart that contains both bars and a line graph, where individual values are represented in descending order by bars, and the cumulative total is represented by the line. The left vertical axis is the frequency of occurrence and the right vertical axis is the cumulative percentage of the total number of occurrences. The purpose of the Pareto chart is to highlight the most common sources of defects. We used general 80/20 rule to identify the 20% of wards that created 80% of overall contamination

Statistic process control (SPC) techniques have played an effective part in monitoring hospital performance. The Geometric SPC chart (*g*-chart) is appropriately used in this study, because the contamination data has an over-dispersion problem, which is shown in histogram of

number between contaminations (Fig 3). *G*-chart analysis is based on inverse sampling to either detect process changes, or verify improvements faster. Prospective *g*-chart analysis is able to trigger specific awareness when relevant increases or decreases of rare events are detected. Such alarms enable timely root cause analysis, so as to secure early clinical process.[15] Also *g*-Chart is appropriate for very low incident event for its take less effort to collect data and can provide real time outbreak detection".

Previously we actually had no formal blood culture monitoring system. This study provides information needed to priority setting, and establishing baseline data for the hospital's quality improvement, which has never been done before. Quality improvement of blood cultures can reduce additional costs, overuse of antibiotics and drug-resistant bacteria in the hospital.

CONCLUSION

We identified 331 false-positive blood cultures, among 32,961 cultured specimens; yielding a contamination rate of 1.0% (95%CI = 0.9 - 1.1). This blood culture contamination rate is very low when compared to other reports. The *g*-control chart is a very effective tool that can detect 14 abnormal variations in 41 locations, by a 3 outbreak criteria comprising of: 1 point under LCL, 2 points under LWL and 5 points under CL.

ACKNOWLEDGEMENTS

We would like to thank Mr.Andrew Jonathan Tait who assisted by editing the English language of the manuscript.

Conflict of interest: All authors of this article certified that there were no financial nor non-financial conflicts of interest.

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