The authors have made every effort to check the accuracy of all information, the dosages of any drugs, and instructions for use of any devices or equipment. Because the science of infection prevention and control is rapidly advancing and the knowledge base continues to expand, readers are advised to check current product information provided by the manufacturer of:

- Each drug, to verify the recommended dose, method of administration, and precautions for use
- Each device, instrument, or piece of equipment to verify recommendations for use and/or operating instructions

In addition, all forms, instructions, checklists, guidelines, and examples are intended as resources to be used and adapted to meet national and local health care settings’ needs and requirements. Finally, neither the authors, editors, nor the Jhpiego Corporation assume liability for any injury and/or damage to persons or property arising from this publication.

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Chapter 1: Basic Epidemiology and Statistics for Infection Prevention and Control

Key Topics

- Basic statistical concepts and methods used to analyze and report infection prevention and control (IPC) data
- Descriptive statistics used for describing health care-associated infections (HAIs)
- Importance of sharing IPC data with key staff
- Data visualization methods and techniques for effective data sharing
- Basic epidemiology for interpreting IPC literature

Key Terms

- **Epidemiology** is the study of the distribution and determinants of health-related conditions or events in specified populations, and the application of this study to the control of health problems.
- **Constant** is a number that is used in the calculation of rates to put the result into a uniform quantity so it can be used for comparisons.
- **Denominator** is the lower portion of a fraction. In the context of HAI surveillance, it is the population at risk for the infection being observed. Examples of denominators in IPC surveillance are numbers of procedures, patient-days, device-days, admissions, and observations.
- **Descriptive statistics** describe the characteristics of data trends and patterns, for example, mean, mode, and median.
- **Exposure** is a factor that may be associated with an outcome of interest. In the context of IPC, an exposure could be contact with an infectious agent (e.g., microorganism), a medical device (e.g., central line), the environment (e.g., dirty water), but also treatments such as antibiotics. Any exposure may result in an increase or a decrease in a condition, such as an infection.
- **Incidence** is the rate at which new events (e.g., surgical site infections [SSIs] or bloodstream infections) occur in a population for a specific period (e.g., SSIs per 100 procedures or bloodstream infections per 100 births).
- **Inferential statistics** make an assumption about a population based on study of a small sample of that population; they are used to calculate the strength of an association between cause and effect, allowing conclusions based on a small subset of people. For example, in an investigation of the strength of association between developing pneumonia and being on a ventilator, all patients on ventilators do not need to be studied, but a representative sample can be used to determine the association.
- **Numerator**, in surveillance, is the number of times an event occurs during a specified time interval. Examples of numerators in IPC surveillance include the number of cases of a specific infection (e.g., SSIs or central line-associated bloodstream infections [CLABSIs]) or the number of occurrences of an event, such as the number of persons who performed hand hygiene.
- **Odds ratio** is used to compare the likelihood of an event occurring among an exposed group and an unexposed group. It typically is used to describe the results of the analysis of an exposed/intervention group and an unexposed/non-intervention group.
• **Outcome measure** indicates the result of the performance (or non-performance) of a function or a process. It may describe a desirable or undesirable event. Outcome measures used in IPC usually describe undesirable events, such as rates of SSIs or CLABSIs.

• **Person-time** is the amount of time accumulated for persons/patients considered at risk for a particular condition. One person-day for urinary catheter means one person having a urinary catheter for 1 day. If in a hospital ward, one patient had a urinary catheter for 10 days or 10 patients had urinary catheters for 1 day, the total person-days for urinary catheters is 10 for this ward. Person-time is often used as a denominator.

• **Prevalence** is the number of existing cases of a particular disease, injury, health condition, or event in a defined population at a given point in time. It includes both new cases and existing cases (e.g., number or patients with HAI present in the hospital today).

• **Process measure** is an indicator that focuses on a process or the steps in a process that lead to a specific outcome. It can be useful to evaluate process measures if they can be linked to an outcome. Process measures are commonly used to evaluate compliance with desired care or support practices or to monitor variation in these practices. Examples of process measures are the proportion of health care workers (HCWs) performing hand hygiene following World Health Organization guidelines, or the proportion of women undergoing cesarean section (C-section) who are given an appropriate dose of perioperative prophylactic antibiotics.

• **Population** is the total number of people with a common characteristic.

• **Proportion** is a type of ratio in which the numerator is included in the denominator; it can be expressed as a decimal (0.5), fraction (1/2), or percentage (50%).

• **Rate** is an expression of the frequency with which an event (e.g., an infection) occurs in a defined population in a given time period. A rate always includes time as a part of its expression.

• **Ratio** is the relative size of two quantities; one number divided by another.

• **Relative risk** compares two groups’ risk of developing a disease or other health event. The groups are often differentiated by demographic factors, such as gender or age. They can also be an exposed and unexposed group. Relative risk provides information about the strength of the association between an exposure and an outcome. It shows how much higher or lower the chance of the outcome is among people who are exposed, compared to people who do not experience the exposure.

• **Risk adjustment** is a statistical process that allows comparison of two outcomes by adjusting for different risks that might affect outcomes. This is done by adjusting for risk factors such as age, body mass index, gender, and other existing conditions that might affect the outcome being measured so that rates from two sources can be compared.

• **Variable** is a quality, property, or characteristic of the person or thing being studied that can be quantitatively measured or enumerated (e.g., age, sex, underlying disease, infections).

**Background**

Infection prevention and control staff need to have a basic understanding of the key principles of statistics as they relate to IPC in order to understand and describe IPC data. Using basic statistical techniques to analyze data will help a facility understand and describe its infection rates and trends over time. IPC staff need to know what data to collect, and how to collect and analyze them. They need to know how to interpret results, present results to key stakeholders, and use data to encourage and guide behavior change. Additionally, IPC staff should be able to understand IPC research in journal articles.
Basic Epidemiology and Statistics

Basics of Epidemiology
As a science, epidemiology has contributed to the improvement of the health of populations around the world and it plays a major role in the identification, mapping, and prevention of emerging diseases. One of its first contributions occurred in the 1850s in London when John Snow, considered to be one of the founders of epidemiology, traced an outbreak of cholera to a public water pump. He did so by mapping the locations of where people who had the disease lived and worked and public water pumps where those with cholera obtained their water. Snow noticed that on the map, houses of people with cholera clustered around one pump; after he presented his data to local authorities, the pump was disabled and the outbreak ended (CDC 2012). Table 1-1 presents an explanation of the definition of epidemiology.

Table 1-1. The Definition of Epidemiology

<table>
<thead>
<tr>
<th>Term</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epidemiology is the study of the distribution and determinants of health-related conditions or events in specified populations, and the application of this study to the prevention and control of health problems.</td>
<td></td>
</tr>
<tr>
<td>Study</td>
<td>Can include surveillance, observation, hypothesis testing, analytic research, and experiments.</td>
</tr>
<tr>
<td>Distribution</td>
<td>The analysis of patterns/diseases according to the characteristics of person, place, and time.</td>
</tr>
<tr>
<td>Determinants</td>
<td>Factors that bring about a change in a person’s health status. These are factors that cause a healthy person to become sick or cause a sick person to recover. Determinants can include both causal and preventive factors. Determinants can be biological, chemical, physical, social, economic, genetic, or behavioral.</td>
</tr>
<tr>
<td>Health-related conditions or events</td>
<td>Include disease, cause of death, behaviors, positive health states, and use of health services.</td>
</tr>
<tr>
<td>Specified populations</td>
<td>Include a group of people with a common characteristic, such as gender, age, or use of a certain medical service.</td>
</tr>
<tr>
<td>Application to prevention and control</td>
<td>The primary goals of public health—to promote, protect, and restore health.</td>
</tr>
</tbody>
</table>

Adapted from: Aschengrau and Seage 2008; Bonita et al 2006; Last 2001.

Basic Statistical Concepts
Populations
As a science, epidemiology is concerned with the health of populations, rather than focusing on the health of individuals. Populations can be defined based on how permanent their membership is. Fixed populations have permanent members who are usually defined by a life event. Once someone is a member of a fixed population, the person will be a member of this population for life. Populations can also be transient, with members joining and leaving the population over time. These are called dynamic, or open, populations. (Aschengrau and Seage 2008)

In the context of a health care facility, the population can be both fixed and dynamic, depending upon the situation. The population of patients visiting a health care facility for treatment is an example of a dynamic population and those admitted to the hospital for a few days is also an example of a dynamic population because patients are admitted and discharged every day.
Patients who underwent any surgical procedure during the last calendar year or patients who had an indwelling catheter during the past 10 days are examples of fixed populations as no new member can be added or removed from this population.

Patients who are at risk of developing a specific HAI are called the “at-risk” population for that HAI. This population will be the denominator when rates of a specific HAI are calculated. For SSI rates, all patients who had any surgery during the time period for which the rates are being calculated make up the “at-risk” population for SSI following all surgery. In a study of SSI rates following C-section, all women who give birth by C-section are the “at-risk” population for SSI following C-section (see Figure 1-1). Other patients, both men and women, who received other surgeries are not part of the “at-risk” population for SSI following C-section.

**Figure 1-1. Determining the Population “At Risk” for a C-Section Surgical Site Infection**

![Diagram](image)

*Adapted from: Bonita et al. 2006.*

**Inferential and Descriptive Statistics**

Being able to analyze populations at risk using basic statistical methods can increase the success of an IPC program by providing a deeper understanding of the problem. There are two types of statistics:

- **Inferential**
- **Descriptive**

Both inferential and descriptive statistics are useful in understanding and describing IPC data.

**Inferential statistics** are used to draw general conclusions about the concerned population, based on studies conducted on a small subset of people (a sample), if the study was properly designed and conducted. A sample size should be calculated by applying recommended statistical methods and the sampling of the study population should be obtained in such a way that the key characteristics of the sample are as close as possible to the whole population. Thus, conclusions from studies that are designed with the correct methodology, although conducted on a small sample, can be applied to a larger population. The use of inferential statistics is a common practice because it is usually not feasible to study a whole population. For example, the beneficial effect of prophylactic antibiotics before surgery for prevention of SSI was observed in an appropriately designed study of a small sample of patients. Based on the findings, it was concluded that all patients who undergo surgery should receive perioperative prophylactic antibiotics for prevention of SSI.

Odds ratios and relative risks are used to describe the association between an intervention and an outcome during a study in order to make generalized recommendations. Detailed discussion of each of
these is beyond the scope of this chapter, but more information on these measures can be found in the references at the end of the chapter.

Descriptive statistics

Descriptive statistics use numbers to describe characteristics of a specific dataset. Descriptive statistics help in summarizing trends and patterns and include discrete and continuous values. Discrete data contain only whole numbers and fall into specified categories (e.g., race or cause of death). Continuous data can have a range of values along a continuum (e.g., height or weight). Rates, such as infection rates, are considered continuous data, since they can contain decimals and are on a continuum. Descriptive statistics are most commonly used for describing surveillance data, for both outcomes and processes.

Descriptive statistics include measures of central tendency (the middle of a distribution), which compare different values in a dataset with the central value. A central tendency describes a typical experience (central value) for the group (e.g., patients, HCWs). Descriptive statistics are used routinely to describe data about an event (infections, compliance with IPC, etc.).

The mean, median, and mode (see Figure 1-2) are the most commonly used central values for describing observed values (e.g., infection) within a dataset. Central values are used to summarize data in a single value, such as the age of persons affected by an outbreak.

The mean is the average number of all values in a dataset. If there are a few extremely large or small values (called outliers) in a series of data, the mean could be artificially higher or lower and may be misleading. Mean is not a sensitive measure to describe the central tendency of a dataset.

The median is the value in a dataset in which half of the values in the dataset are above it and half of the values are below it. Unlike the mean, the median is not affected by extreme outliers in the dataset. While the median is useful as a descriptive measure, it is not often used for further statistical manipulations.

The mode is the most frequently occurring number in a dataset. Mode can be used to describe, for example, which day of the week people prefer to come to a vaccination clinic, typical number of doses of a vaccine or medicine, or the number of days a patient is on a device. Like the median, the mode is useful as descriptive measure, but it is not often used for further statistical manipulations. A dataset with two values occurring equally frequently is called bimodal and a dataset with more than two modes is called multimodal.
Calculating mean, median, and mode

Calculating mean

Table 1-2. Length of Stay for Patients in Medical Ward A

<table>
<thead>
<tr>
<th>Patient</th>
<th>Length of Stay (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>22</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>9</td>
<td>3</td>
</tr>
</tbody>
</table>

Total days: 73

The mean is calculated by adding up all of the values in the dataset (see Table 1-2) and then dividing by the number of values in the dataset. The dataset in Table 1-2 has nine values. To calculate the mean, add the nine values:

\[
\begin{align*}
4 + 10 + 12 + 22 + 2 + 6 + 8 + 6 + 3 & = 73 \\
\end{align*}
\]

Then, divide 73 by the number of values in the dataset, which is 9.

\[
\frac{73}{9} = 8.1 \text{ days}
\]

The mean length of stay is 8.1 days. This number indicates that on average a patient stays in the hospital for 8.1 days. A health care facility manager could use this to evaluate if such a stay is justified or if the quality of care needs to be improved so that the mean length of stay can be reduced to achieve cost savings and reduce the risk of HAI.

The mean length of stay is 8.1 days; however, six of the nine values in the dataset are below 8.1. This is because the mean has been affected by the outlier of 22.

Calculating median

The median is calculated by lining up the values in the dataset in ascending or descending order and finding the middle value. The median is not affected by any outlier value. To calculate the median of this dataset, first rearrange the values in ascending order. The organized dataset now looks like this (see Table 1-3).
Basic Epidemiology and Statistics

Once the individual values in the dataset are organized in ascending order, apply the formula for calculating the median: \( \text{median} = \frac{n+1}{2} \), where \( n \) is the number of individual values in the dataset.

With this formula, if \( n \) is an odd number, the middle value will fall on a single observation and that value is the median. If \( n \) is an even number, the middle value falls between two observations; the average of the two adjacent values will be the median.

In the dataset above, there are 9 values so \( n = 9 \) and the median will be \( \frac{9+1}{2} = 5 \). The fifth value of the dataset is the median, which is Patient 8 with a length of stay of 6 days. Therefore, the median length of stay for this dataset is 6 days. The extreme outlier of the 22-day admission did not affect the median.

Calculating mode

The mode is the most frequently appearing value in the dataset. Sometimes datasets can have more than one mode. In the dataset in Table 1-3, every value appears once, except 6 days, which occurs twice. The mode is 6 days because it is the most frequently appearing value in the dataset.

How to interpret mean, median, and mode for length of stay

Mean, mode, and median allow us to present multiple values in a dataset using just three numbers. Mean takes into account all values in a dataset and generates a single value that can be used to compare one dataset with another. However, mean gets skewed by extremely large or small values but still allows comparison. Describing the range along with the mean allows better interpretation of the dataset. For example, a mean of 8.1 days with a range of \((22-2 = 20)\) 20 days indicates that there is a greater variability in the dataset and not all values are close to the mean. On the other hand, the median (6 days), which is the middle value of the dataset, is not affected by outliers. In the above example, if 2 and 22 were not included in the calculation, the mean would still be close to 6 days. The mode is the value that occurs most frequently in a dataset and shows that, most frequently, patients stay in this facility for 6 days.

Measuring Variability

Measures of variability look at how the values in the dataset are distributed around the mean. Range, deviation, standard deviation, and variance are all measures of variability (see Table 1-4). Most of these measures of variability are not used in day-to-day reporting of data related to IPC. However, the range is the exception.

The range of values—the difference between the smallest and largest values—is commonly calculated for an IPC dataset. For instance, you may want to calculate the range of lengths of stay to help further investigate how long patients tend to stay in the health care facility. Another example is the range of the number of days patients have an indwelling urinary catheter in place before developing a catheter-associated urinary tract infection (CAUTI).
Calculating the range

Range is calculated by subtracting the smallest number in the dataset from the largest number. In the dataset in Table 1-3, Patient 5 had the shortest length of stay (2 days) and Patient 4 had the longest length of stay (22 days). To calculate the range, subtract the shortest length of stay from the longest length of stay:

\[
22 \text{ days} - 2 \text{ days} = 20 \text{ days}
\]

The range of length of stay for these patients was 20 days. More precisely, the length of stay for these patients ranged from 2 to 22 days.

Table 1-4. Measures of Disease Variability

<table>
<thead>
<tr>
<th>Term</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>A value that shows the difference between the highest and lowest values in a dataset.</td>
</tr>
<tr>
<td>Variability</td>
<td>The spread of values within a dataset. If variability is small, all values are close to the mean. If variability is large, the values are spread out and are not close to the mean. Variability is measured using range, variance, and standard deviation.</td>
</tr>
<tr>
<td>Deviation</td>
<td>A value that shows the spread of each individual value from the mean of the overall dataset. A negative deviation means that the individual measurement is less than the mean, a positive deviation means that the individual measurement is greater than the mean, and no deviation means that the individual measurement is the same as the mean.</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>A measure of the dispersion (spread) of raw values that reflects the variability of values around the mean value of the dataset. It gives more emphasis to larger deviations and less emphasis to smaller deviations. Means should be reported with their standard deviations. The values of standard deviations convey how widely and narrowly the values are distributed around the mean.</td>
</tr>
<tr>
<td>Standard Error of the Mean</td>
<td>A measure used for comparative purposes, the standard error of the mean is the standard deviation adjusted for by the sample size. It is used in calculating confidence intervals.</td>
</tr>
<tr>
<td>Variance</td>
<td>A way of measuring the variability of values included in a dataset. Standard deviation is more frequently used to measure variability than variance.</td>
</tr>
</tbody>
</table>

Source: APIC 2014c.

Measuring Disease Occurrence

IPC surveillance will produce a dataset of raw numbers (e.g., number of patients with SSIs, number of patients who had an indwelling urinary catheter and developed a urinary tract infection). Although this is helpful and necessary information, the raw numbers may be misleading as they do not allow for comparison or indicate if there is truly a problem. For example, even if two sites each reported 10 SSIs last month, they cannot be compared unless the data on the at-risk population (the denominator) are available. The standalone count of events needs to be put into context by including the populations from which it came—the at-risk population. For example, at the first site, 50 patients received surgery while 100 patients received surgery at the second site. Using the number of SSIs as the numerator and
the total number of patients who received surgery (i.e., the at-risk population) as the denominator to calculate ratios, proportions, and rates allows the sites to be compared: the second site had lower rates of infection (10/100 or 10%) than the first site (10/50 or 20%).

**Rates** measure the probability of a particular event, such as an infection or death, occurring in a population. Rates help expand the focus from the numerator and give perspective. A critical part of calculating rates is to know how to identify the numerator and denominator. Calculating rates over a period of time allows rates to be compared.

The numerator, in the calculation of a rate, is typically the number of times the event occurred during a specific time interval. For HAIs, this usually represents the number of a specific type of infection identified over a time period.

The denominator for calculating rates (e.g., for HAIs) is the population at risk, or the number of patient-days of risk, during the same interval used for collecting data about the numerator. For IPC processes (e.g., hand hygiene), the denominator would be the number of possible infection prevention opportunities for that process (e.g., hand hygiene opportunities). Picking the right denominator is very important when measuring disease occurrence. Picking the wrong denominator can lead to inaccurate rates and thereby to a wrong conclusion about what is truly occurring in the population.

A time parameter is needed, when determining rates, in order to identify the time period during which infections (or events) and the population at risk are counted. The time parameters must be the same period used for counting both the numerator and the denominator.

A constant is used to put the result into a uniform quantity so comparisons between rates can be made. The constant is selected based on how frequently the event occurs; generally, it is globally agreed upon. For example, SSI is expressed as percentages (per 100), CAUTI as number of urinary tract infection per 1,000 catheter-days, and hand hygiene compliance as percentage of hand hygiene opportunities.

To summarize, there are three important things to remember when calculating a rate:

- The numerator and denominator must reflect the same population—cases that are in the numerator must also be counted in the denominator.
- All cases in the denominator are eligible to be considered for the numerator.
- Counts in the numerator and denominator must cover the same time period.

(APIC 2014b)
### Box 1-1. Example of a Rate Calculation

**Calculating SSI rates following C-section at District Hospital**

**Numerator:** Number of women who delivered by C-section who had an SSI during a given period of time at the health care facility:

- **14 SSIs following a C-section during April 2016**

**Denominator:** All women who delivered by C-section (population at risk) during the same period at the health care facility:

- **140 C-sections during April 2016**

**SSI rates following C-section = numerator/denominator x constant**

- **14/140 x 100 = 10% during April 2016**

The SSI rate following C-section during April 2016 at District Hospital was 10%.

### Measuring Disease Frequency

Incidence and prevalence are the most common ways to measure disease frequency. Incidence measures the new occurrence of a disease or event, while prevalence is the total number of cases of a particular disease in a given population. (Aschengrau and Seage 2008)

#### Incidence

Incidence measures new cases of a disease or condition that occur in a specified population over a given time period, and thus looks *only* at new cases. Other terms used to express incidence include attack rate, risk, and probability of getting a disease. Incidence generally refers to the rate at which new events occur in a population. Incidence takes into account the variable time period during which individuals are disease-free and thus, “at risk” of developing disease.

The numerator for calculating incidence is the number of new events that occur in a defined time period. The denominator is the population at risk of experiencing the event during the time period. (Bonita et al. 2006)

**Formula for calculating Incidence:**

\[
\text{Incidence} = \frac{\text{No. of new cases of a disease in a specific period of time}}{\text{No. of persons at risk of developing the disease during the specified period of time}} \times \text{Constant (100; 1,000; or 100,000)}
\]

For example, to calculate the incidence of SSIs following C-sections, the numerator will be the women developing an SSI after a C-section over a defined period of time and the denominator will be the women who had a C-section during the same time period (see Box 1-1). (See Chapter 2, Introduction to Surveillance of Health Care-Associated Infections, in this module for information on how HAIs, including...
SSIs, are defined.) Any woman who is included in the denominator (all women having C-sections) must have the potential to become part of the numerator (developing SSI following C-section).

There are many different types of incidence rates calculated in the IPC setting (see Table 1-5).

**Table 1-5. Commonly Used IPC Metrics**

<table>
<thead>
<tr>
<th>Incidence Rates</th>
<th>How to Calculate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgical site infection (SSI) rates, postpartum sepsis rates</td>
<td>(# of infections/# of procedures) x 100 procedures</td>
</tr>
<tr>
<td>Central line-associated bloodstream infections (CLABSI) rates</td>
<td>(# of CLABSI/# of central line-days) x 1,000 central line-days</td>
</tr>
<tr>
<td>Catheter-associated urinary tract infection (CAUTI) rates</td>
<td>(# of CAUTI/# of indwelling urinary catheter-days) x 1,000 urinary catheter-days</td>
</tr>
<tr>
<td>Ventilator-associated pneumonia (VAP) rates</td>
<td>(# of VAP/# of ventilator-days) x 1,000 ventilator-days</td>
</tr>
<tr>
<td>Multidrug-resistant organism (MDRO) rates (e.g., methicillin-resistant Staphylococcus aureus [MRSA] rates)</td>
<td>(# of MDRO infections/# of patient-days) x 1,000 patient-days</td>
</tr>
<tr>
<td>Health care associated-bloodstream infection (sepsis), health care-associated pneumonia, etc., rates</td>
<td>(# of infections/# of patient-days) x 1,000 patient-days</td>
</tr>
<tr>
<td><em>Clostridium difficile</em> rates*</td>
<td>(# of <em>C. difficile</em> infections/# of patient-days) x 10,000 patient-days or 1,000 patient-days</td>
</tr>
</tbody>
</table>

* *C. difficile* rates may use a constant of either 1,000 or 10,000, but whichever is used, it should be used consistently.

The formula used for calculating infection rates can also be used for calculating rates of correct performance of a desired action, such as hand hygiene (see Table 1-6). For example, the numerator is the number of times hand hygiene is correctly performed by HCWs and the denominator is the number of opportunities hand hygiene should have been performed based on the World Health Organization’s “My 5 Moments for Hand Hygiene.”

**Table 1-6. Calculation of Hand Hygiene Compliance**

<table>
<thead>
<tr>
<th>Incidence Rates</th>
<th>How to Calculate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand hygiene compliance rates (i.e., hand hygiene performed correctly when indicated)</td>
<td>(# of times hand hygiene is performed correctly/# of opportunities for hand hygiene) x 100</td>
</tr>
<tr>
<td></td>
<td>Example: Hand hygiene compliance rates in a medical ward in a large hospital</td>
</tr>
<tr>
<td></td>
<td>400 (number of observations when hand hygiene was correctly performed)/1,000 (total number of opportunities when hand hygiene should have been performed) x 100 = 40%</td>
</tr>
</tbody>
</table>
**Incidence Density**

A specific type of incidence rate frequently used in IPC is incidence density (see Table 1-7). Incidence density is the occurrence of new events (e.g., cases of an infection) that arise during observation of total person-time at risk. This is a more sensitive measure of incidence than just considering the size of the population at risk because it takes into account the period of time the population was exposed to the risk. The denominator for incidence density is the sum of person-time at risk accumulated by each member of the population at risk. The rates are described as number of infections/period of exposure to the risk (for example, days). This means that the longer a person is considered at risk, the more time the person will contribute to the denominator for incidence density. In health care IPC measures, person-time at risk is usually represented using patient-days or device-days. For example, in determining CLABSIs, the denominator is central line-days. Each patient contributes 1 day to the denominator for each of the days that he or she has a central line in place. A patient who has a central line in place for 5 days is at risk of getting a CLABSI for 5 days and will contribute 5 central line-days to the denominator. (Aschengrau and Seage 2008)

\[
\text{Incidence Density} = \frac{\text{Number of cases or events during observation time period}}{\text{(Total person-time for the population)} x \text{constant}}
\]

Example: Calculating Incidence Density Rate for CLABSI

**Table 1-7. Number of Central Line-Days in April**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Number of Days Patients Had a Central Line while in the Health Care Facility in April</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>22</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>19</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>9</td>
<td>28</td>
</tr>
<tr>
<td><strong>Total central line-days</strong></td>
<td><strong>142</strong></td>
</tr>
<tr>
<td><strong>Total number of CLABSIs during April 2016</strong></td>
<td><strong>2</strong></td>
</tr>
</tbody>
</table>

The **numerator for calculating incidence density for CLABSI** is 2—total number of CLABSIs during April 2016.

The **denominator for calculating incidence density** is 142—the number of days that patients had a central line in place.

The constant typically used for device-associated rates is 1,000 device-days.
The CLABSI incidence density for April 2016 = (# new CLABSIs/# central line-days) x constant = (2/142) x 1,000 central line-days = 14.08.

The facility had a CLABSI rate of 14.08 infections per 1,000 central line-days in April 2016.

The simple incidence rate (as compared to incidence density) in this case would be 2/9 patients x (1,000) = 222.22 per 1,000 admissions.

As with other measurements, these numbers should be compared with previous facility rates, rates for similar facilities, and other benchmarks. The incidence rate (222.22 per 1,000 admissions) does not consider the length of time central lines were in place and thus will miss a very important fact that the longer the patient is on a central line the higher the probability is of developing a CLABSI. This is captured by the incidence density rate (14.08 per 1,000 central line-days).

**Prevalence**

Prevalence of a disease or condition is the number of existing cases and it represents the proportion of the total population that has the disease or condition. Prevalence accounts for all existing cases. This is an important difference from incidence, because incidence looks only at new cases of the disease or condition. Prevalence is a very effective measure to express burden of disease in a population. (Aschengrau and Seage 2008)

There are two main types of prevalence (see Box 1-2):

- Point prevalence
- Period prevalence

Point prevalence refers to the proportion of the total population at risk that has the disease at a specified point in time. In contrast, period prevalence refers to the proportion of the at-risk population that has the disease over a specified interval of time. Both point prevalence and period prevalence look at the number of existing cases of disease or events.

**Box 1-2. Point and Period Prevalence**

<table>
<thead>
<tr>
<th>Type of Prevalence</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Point Prevalence</strong></td>
<td>(Number of existing cases of disease/Total at-risk population) <strong>at a given point in time</strong> (e.g., on April 1, 2016)</td>
</tr>
<tr>
<td><strong>Period Prevalence</strong></td>
<td>(Number of existing cases of disease/Total at-risk population) <strong>over a specified period of time</strong> (e.g., during April 2016)</td>
</tr>
</tbody>
</table>

The difference between point prevalence and period prevalence is in the time interval that they address. Point prevalence studies give a snapshot of the burden of disease at a specific point in time, whereas period prevalence studies are able to show the burden of disease over a longer time period. Prevalence ranges from 0 to 1, or it can be expressed as a percentage by multiplying by 100.
Formula for calculating prevalence:

\[
\text{Prevalence} = \frac{\text{No. of existing (old and new) cases of a disease in a specific period}}{\text{No. of persons at risk of developing the disease during this period}} \times \text{Constant (100; 1,000; or 100,000)}
\]

Example: Point Prevalence of Infection in a Health Care Facility

On April 1, 2016, there were 120 patients in a medical ward in a health care facility; 7 of these patients currently had a gastro-intestinal (GI) infection.

Point prevalence = 7 (number of cases of GI infections on April 1, 2016, among patients in the medical ward)/120 (number of patients in the medical ward on April 1, 2016, in the health care facility) x 100

\[
7/120 = 0.05833 \times 100 = 5.83\%
\]

The point prevalence of GI infections among patients admitted to the health care facility on April 1, 2016, was = 5.83%.

Example: Period Prevalence of Infection in a Health Care Facility

During the calendar year 2016, 900 C-section were performed at a tertiary hospital. The preoperative assessment revealed that 150 women had diabetes (both Types I and II).

Period prevalence = 150 (women undergoing C-section having diabetes during 2016)/900 (pregnant women delivering by C-section) x 100

\[
150/900 = 0.1666666 \times 100 = 16.66\%
\]

During the calendar year 2016, the period prevalence of Types I and II diabetes among women who had a C-section at this tertiary care hospital was 16.66%.

Choosing to use incidence or prevalence

Figure 1-3 shows the relationship between incidence and prevalence. Incidence, new cases, is depicted by the new water entering the bathtub. Prevalence is shown by the level of water currently in the bathtub. This includes water that is entering the tub and water that was already in the tub. Prevalence includes all disease cases at a given time, both the new cases and existing cases. Water leaves the tub via evaporation or via the drain. In the figure, the water that evaporates can be thought of as patients who have recovered, and the water that leaves via the drain can be thought of as patients who have died. Patients who have recovered from the event or patients who have died are not counted when determining prevalence.
Prevalence gives more precise information on the burden of disease, whereas incidence provides more precise information on the risk of occurrence of disease in a population. Prevalence is often used by program managers to allocate resources to manage cases, whereas incidence is often used to assess the risk of infection and take preventive measures to reduce the risk. The difference between incidence and prevalence is summarized in Table 1-8. Table 1-9 compares the advantages and disadvantages of calculating incidence and prevalence.

**Table 1-8. Comparing Incidence and Prevalence**

<table>
<thead>
<tr>
<th>Incidence</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used to measure the “risk” of a disease or an event occurring in a population.</td>
<td>Used to measure the “burden” of disease in a given population.</td>
</tr>
<tr>
<td>It is mainly used to measure acute disease conditions, but it is also used for chronic diseases. Often used in studies of causation.</td>
<td>Estimates the probability of the population being ill at the period of time being observed.</td>
</tr>
<tr>
<td>Measures new cases of a disease/an event in a population at risk of developing the disease/event.</td>
<td>Measures existing cases of a disease/an event either at a point in time or over a period of time in a population.</td>
</tr>
<tr>
<td>Numerator includes only new cases of a disease/an event.</td>
<td>Numerator includes all existing cases of a disease/an event including old and new cases.</td>
</tr>
<tr>
<td>Denominator is the number of people in the population at risk during a specified time period. It can be the person-time of exposure if calculating incidence density.</td>
<td>Denominator is the number of people in the population at risk at or during the specified time.</td>
</tr>
</tbody>
</table>
Table 1-9. Advantages and Disadvantages of Calculating Incidence and Prevalence in IPC

<table>
<thead>
<tr>
<th>Measure</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevalence</td>
<td>Ideal for capturing overall picture at a point in time</td>
<td>Can be influenced by the duration of the patient’s stay</td>
</tr>
<tr>
<td></td>
<td>Less resource-intensive</td>
<td>Results may not always be statistically significant in small hospitals or units</td>
</tr>
<tr>
<td></td>
<td>Requires less time</td>
<td>Can be challenging to determine whether an infection is still “active” on the day of the study</td>
</tr>
<tr>
<td></td>
<td>Less expensive to conduct</td>
<td></td>
</tr>
<tr>
<td>Incidence</td>
<td>Ideal for targeted surveillance over time</td>
<td>More resource-intensive</td>
</tr>
<tr>
<td></td>
<td>Can effectively detect differences in infection rates</td>
<td>Can be expensive</td>
</tr>
<tr>
<td></td>
<td>Useful for inter-hospital and inter-ward comparisons</td>
<td>Can be time-consuming to collect data over a longer period of time</td>
</tr>
<tr>
<td></td>
<td>Helpful for tracking trends over time</td>
<td></td>
</tr>
</tbody>
</table>


Besides incidence and prevalence, there are additional measures of disease frequency used in public health and hospital epidemiology (see Table 1-10). Detailed discussion of each of these is beyond the scope of this chapter, but more information on these measures can be found in the references at the end of the chapter.

Table 1-10. Additional Measures of Disease Frequency Used in Public Health

<table>
<thead>
<tr>
<th>Measure of Disease Frequency</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude mortality rate</td>
<td>Total number of deaths from all causes per 100,000 population per year</td>
</tr>
<tr>
<td>Cause-specific mortality rate</td>
<td>Number of death from a specific cause per 100,000 per year</td>
</tr>
<tr>
<td>Age-specific mortality rate</td>
<td>Number of deaths from all causes for individuals within a specific age category per 100,000 population per year in the specific age category</td>
</tr>
<tr>
<td>Infant mortality rate</td>
<td>Number of deaths of infants less than 1 year of age per 1,000 live births per year</td>
</tr>
<tr>
<td>Morbidity rate</td>
<td>Number of existing or new cases of a particular disease per 100 population</td>
</tr>
<tr>
<td>Attack rate</td>
<td>Number of new cases of disease that develop (in a given time period) per number of population at risk at the start of the time period</td>
</tr>
<tr>
<td>Case fatality rate</td>
<td>Number of deaths per number of cases of disease</td>
</tr>
</tbody>
</table>

Adapted from: Aschengrau and Seage 2008.
Standardized infection ratio

The standardized infection ratio (SIR) is a summary measurement that compares the number of reported HAIs among a group of patients to the number of predicted or expected infections, based on a standard population. SIRs are risk-adjusted, so they incorporate specific patient risk factors or facility risk factors that may lead to an increased occurrence of disease. Risk adjustment is a statistical process used to adjust for variation in outcomes that occurs due to differences in risk factors or specific characteristics (The Joint Commission 2016). These risk factors are elements that may impact the number of infections reported within a health care facility, such as the number of beds at a facility, whether a hospital is associated with a medical school, and the high community-onset prevalence rate (e.g., the rate of infections that occur ≤ 3 days after admission). (CDC 2016; Dudeck et al. 2013)

Standardized infection ratios are usually calculated by a national-level body and each SIR is procedure/specialty-specific and based on risk factors for facility type (e.g., type and size of facility) and patients (e.g., duration of surgery, age). The SIR is a comparison of observed HAIs and predicted or baseline HAIs, usually based on data from previous years.

\[
\text{SIR} = \frac{\text{Observed HAIs}}{\text{Predicted HAIs}}
\]

SIR > 1: The number of infections is above the baseline, which indicates the need for interventions to reduce the number of HAIs.

SIR = 1: The number of infections is the same as the baseline, which indicates the need for further improving interventions to reduce the HAIs such that the SIR is less than 1.

SIR < 1: The number of infections is below the baseline, which indicates that the HAI prevention interventions are working and should be further strengthened and continued. The goal is zero HAIs.

Examples: If District Hospital has a CLABSI rate of 3 per 1,000 central line-days and the national data predict 2 CLABSIs per 1,000 central line-days, the SIR for CLABSIs for the facility is: \( \text{SIR} = \frac{3}{2} = 1.5 \). This means that the CLABSI infection rate in District Hospital is 1.5 times the predicted national average and steps need to be taken to reduce infection rates. (CDC 2016)

Many low- and middle-income countries are working toward reporting national HAI rates that can be used for calculating SIRs at the facility level. If national rates are not available, data from previous years or from comparable facilities can be used to track HAI prevention progress over time.

Data Feedback and Sharing

Data feedback mechanisms and data sharing techniques are important because IPC results are most effective when they are shared in a timely manner. All results based on data analysis should be shared soon after the data are collected so that meaningful and timely interventions can be implemented. This presents a unique challenge with surveillance data on HAIs because it takes days or weeks to perform the surveillance itself.

When sharing IPC data, it is important to consider how to best present the data so that the desired message is most effectively communicated. Different data should be shown in different ways. For example, some data are best shown in a graph, whereas other data are best shown in a table. It is also
important to take into account with whom the data are being shared and the goals of the data sharing. Not everyone will have a background in statistics; therefore, the data should be clearly presented and easy to understand in order to maximize the effectiveness of the data sharing.

Tables, graphs, and charts are all common ways to share IPC data:

- A table is a set of data arranged in rows and columns, detailing various elements of the data.
- Graphs show quantitative (i.e., measurable) data and are useful in showing data over long periods of time.
- Charts, such as pie charts, are useful in comparing the magnitude of data or in showing pieces of the whole picture.

(APIC 2014c)

(See Appendix 1-A. Visual Displays of Data.)

**Using Epidemiology to Drive Policy**

Epidemiological data can be helpful in influencing health practices and policies, both at the facility level and at the local and national levels. Good data collection and analysis of findings can help health care facilities understand where patient safety risks are occurring and can help a facility prioritize resources for IPC. Tracking IPC data over time can show when there is a true increase or decrease in HAIs. This information can then be used to change practices and policies in the health care setting.

It is important to share IPC data with key stakeholders, including ward-level staff, providers, and facility leadership. Data sharing should always be transparent. Share both the good results and the areas where immediate improvements are needed and initiate actions based on the interpretation of data. Make sure to let those who helped implement a successful intervention know that their hard work led to a change in practice. This will encourage the ward staff to continue prevention efforts and let facility leadership know the value of the IPC team. It will also help create positive relationships between the IPC team and others at the facility.

**Understanding IPC Literature and the Basics of Epidemiological Studies**

Reading IPC literature (journal articles) and understanding the findings of relevant research studies allow IPC staff to practice more effectively. Epidemiological studies are commonly designed to look at the causes of a condition or an event, effectiveness of prevention interventions, and treatments of disease. These studies are conducted not only to measure characteristics of the study’s subjects, but also to make generalizations about applying the finding to the larger population from which these subjects came. IPC literature may provide information on a new prevention method or on an evidence-based prevention practice that has been shown to be effective at reducing HAI rates. The literature may also include information on HAI rates at similar facilities that can be used for comparison with current facility rates. Therefore, it is important to have a basic understanding of how the studies were conducted and how to interpret any major findings. (Aschengrau and Seage 2008; CDC 2012)

Epidemiological studies consist of observational and experimental studies. The purpose of these studies is to identify and quantify the relationship between an exposure (e.g., to an intervention such as a new drug, a new approach to manage a medical condition, counseling for clients in the community, or risks such as exposure to an infection) and a health outcome (e.g., incidence of a disease, uptake of services). In each study there are at least two groups, one of which serves as a comparison or control group.
The article titled “Chlorhexidine bathing and health care-associated infections: a randomized clinical trial,” was an experimental study that compared the outcomes of a group patients who were bathed daily with disposable cloths impregnated with 2% chlorhexidine (the exposure) with those of a group of patients (the control group) who were bathed daily with non-antimicrobial cloths (Noto et al. 2015):

- **Observational studies** do not include any manipulation of variables or exposures by the investigator. Examples of observational studies are investigations of the incidence of health care-associated viral respiratory infections on pediatric wards with single or shared rooms, or observations of SSIs among all patients who undergo surgery and a report of the SSI rates. The investigator does not manipulate variables but just observes the outcome and reports the results.

- **In experimental studies**, the investigator manipulates one or more of the variables or exposures. An example of an experimental study is an assessment of hand hygiene compliance before and after an educational training session. The goal of this study would be to determine if the educational session had any impact on hand hygiene compliance rates.

Experimental studies, when appropriately designed, are considered to be the gold standard and yield the most reliable data. However, there are often reasons, including ethical issues, that experimental studies cannot be performed. In these circumstances, observational studies are commonly used. For example, an investigator may want to look at how the case fatality rate changes if patients are given antibiotics, compared to patients from whom antibiotics are withheld. Although an experimental study would yield the most reliable data, it would be unethical to purposely withhold antibiotics from patients when antibiotics are known to effectively reduce mortality, so the investigator conducts an observational study instead. For example, a retrospective study could be conducted of all cases of sepsis to determine the outcomes of those who were given antibiotics as part of their care and those who (for some naturally occurring reason) did not receive antibiotics.

The main types of observational studies used in epidemiology are cohort studies and case-control studies (see Table 1-11).
Table 1-11. Summary of Epidemiological Studies

<table>
<thead>
<tr>
<th>Type of Study</th>
<th>Study Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>Studies ways to prevent or treat diseases/events; investigator actively controls which subjects receive the agent or exposure under study and tracks the outcome of the individual or community.</td>
</tr>
<tr>
<td>Observational</td>
<td>Studies causes, preventions, and treatments of diseases/events; investigator passively observes an exposure as nature takes its course.</td>
</tr>
<tr>
<td></td>
<td>- <strong>Cohort study</strong>: Examines multiple health effects of an exposure; subjects are defined according to their level of exposure and subjects are followed over time to determine the outcome—if disease or an event occurs.</td>
</tr>
<tr>
<td></td>
<td>- <strong>Cross-sectional study</strong>: Examines the relationship between exposure and disease prevalence in a defined population at a single point in time.</td>
</tr>
<tr>
<td></td>
<td>- <strong>Case-control study</strong>: Examines multiple exposures in relation to a disease or event: subjects are defined as cases (those who have the event or disease) and controls (those who do not have the event or disease) and their exposure history is investigated and compared.</td>
</tr>
<tr>
<td></td>
<td>- <strong>Ecological study</strong>: Examines the relationship between exposure and disease with population-level disease and exposure, rather than individual level of disease and exposure.</td>
</tr>
</tbody>
</table>

*Adapted from: Aschengrau and Seage 2008.*

The IPC literature contains statistical terms that assess the strength of association (relationship) between the risk factor (exposures) and the outcome (a disease). Commonly used terms describing strength of association include the odds ratio, relative risk, confidence interval, p-value, and statistical significance. Other terms describe factors that could have influenced the strength of association, including bias, confounding, and chance. Table 1-12 provides a high-level summary of the measures that can be used to interpret and understand the literature.

Table 1-12. Statistical Terms Used in IPC Literature

<table>
<thead>
<tr>
<th>Term</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Odds Ratio (OR)</td>
<td>Odds ratio is used to compare the likelihood of an event occurring among an exposed group and an unexposed group. It typically is used to describe the results of the analysis of an exposed/intervention group and an unexposed/non-intervention group.</td>
</tr>
<tr>
<td></td>
<td>An odds ratio of 1.0 means that the likelihood of an event/effect occurring among both exposed and unexposed groups or intervention and non-intervention groups is the same. An OR of &gt; 1.0 means that the likelihood of an event/effect occurring in the exposed/intervention group is higher than in the non-intervention group. An OR of &lt; 1.0 means that the likelihood of an event/effect occurring in the intervention group is less than in the non-intervention group.</td>
</tr>
<tr>
<td></td>
<td>For example, one study reported that compliance with hand hygiene among HCWs in a facility when alcohol-based handrub (ABHR) was available has an OR of 2, which means that HCWs who had ABHR available were twice as likely to perform hand hygiene as HCWs in a facility where ABHR was not available. (Lindsjö et al. 2015)</td>
</tr>
<tr>
<td>Term</td>
<td>Explanation</td>
</tr>
<tr>
<td>--------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Relative Risk (RR)</td>
<td>Relative risk compares two groups’ risk of developing a disease or other health event. The groups are often differentiated by demographic factors, such as gender or age. They can also be an exposed and unexposed group. For example, RR is the risk of the intervention group (those receiving chlorhexidine bathing) developing a disease (an HAI) compared to the risk of the non-intervention group (those not receiving chlorhexidine bathing) developing a disease. Relative risk provides information about the strength of the association between an exposure and an outcome. It shows how much higher or lower the chance of the outcome is among people who are exposed, compared to people who do not experience the exposure. An RR of 1.0 indicates that both groups have the same risk of developing the outcome. For example, there is no difference in the risk of developing an HAI among those who received chlorhexidine bathing and those who did not (Noto et al. 2015). A RR of &gt; 1.0 means that the risk of the exposed group developing disease is greater than among those not exposed. For the chlorhexidine bathing intervention, it means there is no protective effect and it may result in increased risk of developing an HAI. A RR of &lt; 1.0 means that there is a protective effect from the exposure.</td>
</tr>
<tr>
<td>P-value</td>
<td>P-value is used to determine whether the likelihood of an observed association (relationship) or difference could have occurred by chance. A P-value of 0.05 means that the likelihood that the observed association or difference occurring by chance is 5 out of 100 or 5%. A p-value of 0.05 or less means that the observed association is real and not by chance. If one conducts such studies 100 times, it is very likely that 95 times one will notice a similar association or difference observed in the study with a P-value of less than 0.05. For example, a P-value of 0.0025 is considered to be statistically significant (the exposure affected the outcome) if a P-value of &lt; 0.05 is used as the cutoff for statistical significance.</td>
</tr>
<tr>
<td>Statistical Significance</td>
<td>Statistical significance describes the results of an experimental study that shows that the observed association or the difference is real and has not happened by an error. When study results are statistically significant, it is unlikely that the results could have occurred by chance alone. In describing surveillance results (both rates of HAIs and compliance with IPC practices), typically a P-value of &lt; 0.05 is used to designate that a finding is statistically significant (unlikely to have occurred by random chance). For example, if in an ABHR study the OR of 2 for compliance with hand hygiene when ABHR was available had a P-value of &lt; 0.05, it means that one can be assured that the increase in compliance was real and not by chance.</td>
</tr>
<tr>
<td>Term</td>
<td>Explanation</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Confidence Interval (CI)</strong></td>
<td>Confidence intervals (CIs) are used to estimate precision. A wide CI indicates less precision; a narrow CI indicates higher precision. In any experimental study, a large sample size will give narrow CIs. Confidence intervals do not determine statistical significance, but are often used as a proxy for statistical significance. If the confidence interval does not overlap the value of 0.00, the findings are considered to be statistically significant.</td>
</tr>
<tr>
<td></td>
<td>In epidemiology, a 95% CI is a range of values that you can be 95% certain contains the true value. It is typically used to demonstrate 95% confidence that the specified interval includes the true value.</td>
</tr>
<tr>
<td></td>
<td>For example, a 95% confidence interval of (1.56–1.70) indicates that if one performs a similar study taking 100 additional samples, one can be 95% certain that the confidence interval will contain the true value and will be statistically significant.</td>
</tr>
<tr>
<td><strong>Bias</strong></td>
<td>Bias is any systemic error in the design, conduct, or analysis of a study that results in a mistaken estimate of an effect of an exposure/intervention. There are various types of bias. Selection bias and observation bias are the two main types. A selection bias can occur if there are systematic differences in how each group (exposed and unexposed) is selected for the study. For example, if the selection method results in selecting a greater number of older persons for the exposed group and a greater number of younger people for the unexposed group, the age difference may influence the results of a study. Another bias is information bias, which can result when a researcher does not include some key information in the report that leads to a different interpretation of data and results.</td>
</tr>
<tr>
<td><strong>Confounding</strong></td>
<td>Confounding occurs when the relationship between two variables is distorted by a third variable that is related to both of the original variables. It is a mixing of effects between an exposure, an outcome, and a third variable (the confounding variable). This can impact the conclusions you are able to draw between the original two variables. For example, while studying CAUTI rates among both male and female patients, it was observed that rates in female patients were twice as high as rates in males. However, on further analysis of data it was observed that student nurses in training inserted indwelling urinary catheters in more than 80% of female patients. When further analysis was made to compare only the patients for whom trained providers inserted catheters, the rates were not much different. Therefore, providers’ training was a confounding factor.</td>
</tr>
<tr>
<td><strong>Random Error</strong></td>
<td>Random errors lead to a false association between the exposure and the outcome, when the association is really only occurring by chance. This can lead one to believe there is a statistically significant difference between the two variables, when in reality, there is not. Random error is reduced by increasing precision and ensuring good study design. A study can increase its sample size in order to increase precision and protect against random error.</td>
</tr>
</tbody>
</table>

Sources: Aschengrau and Seage 2008; CDC 2012; Rothman 2002; Szumilas 2010.
Summary
Using basic statistical methods and techniques to analyze data will help a facility understand its infection rates and trends over time. Calculating basic rates, incidence, and prevalence are all useful for understanding IPC performance in the health care setting. The IPC team that has a basic understanding of hospital epidemiology and statistics will be able to interpret and share data effectively. The IPC team should be able to share data in a clear, concise, and effective way in order to use the data to influence behavior and guide change. All results based on data analysis should be shared soon after the data are collected so that meaningful and timely interventions can be implemented. Reading IPC literature (journal articles) and understanding the findings of relevant research studies allow IPC staff to practice more effectively.
Appendix 1-A. Visual Displays of Data

Graphs and Tables
In the sharing of IPC data, different data should be shown in different ways. For example, some data are best shown in a graph, whereas other data are best shown in a table. It is important to take into account with whom the data are being shared and the goals of the data sharing.

Tables, graphs, and charts are all common ways to share IPC data:

- A table is a set of data arranged in rows and columns, detailing various elements of the data.
- Graphs show quantitative (i.e., measurable) data and are useful in showing data over long periods of time.
- Charts, such as pie charts, are useful in comparing the magnitude of data or in showing pieces of the whole picture.

(APIC 2014c)

The goal of utilizing visual techniques, such as tables, graphs, and charts, is to share enough data in the display so that the reader can understand the data without having to read any additional text (see Table A-1) (Bonita et al. 2006). Simple graphs and charts can be made using Excel and displayed in PowerPoint.

Table A-1. Advantages of Graphs and Tables

<table>
<thead>
<tr>
<th>Advantages of Graphs</th>
<th>Advantages of Tables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple and clear</td>
<td>Able to show more complex data with more precision and flexibility</td>
</tr>
<tr>
<td>Memorable visual images for the reader</td>
<td>Able to include more details</td>
</tr>
<tr>
<td>Able to show complex relationships</td>
<td>Do not require technical skills or statistical skills to create</td>
</tr>
<tr>
<td>Emphasize numbers</td>
<td>Take up less space for a given amount of information</td>
</tr>
</tbody>
</table>

Adapted from: Bonita et al. 2006.

Properly formatted tables and graphs will help the reader understand and interpret data. Titles and labels are helpful. Titles should contain specific information describing exactly what the data are showing, where the data came from, and when they were collected. When a graph is missing key elements, such as titles and axis labels, it is may be unclear what the data represent. This can lead to confusion and even misinterpretation of the data. When making graphs, it is also important to think about the scale of the axis and ensure it is evenly distributed (see Figure A-1). (Bonita et al. 2006; CDC 2012)
Graphs

A good-quality graph has the following key features:

- **Title**: The title should clearly communicate the basic information about the data being presented. In the graph on SSI rates, the title tells the reader that the graph is about the rates of SSIs for different types of surgery (what) at Healthy Hands Hospital (where) during the year 2016 (when) (see Figure A-2).

- **Axis labels**: Both the horizontal axis (Procedure Types) and the vertical axis (SSI Rates %) should be appropriately labeled. The horizontal axis label helps readers understand that the data are about different surgical procedures and the vertical axis label helps readers understand that the numbers on this axis represent the SSI incidence rates per 100 procedures (%) in each category and not the number of infections.

- **Data labels**: Data labels provide information on individual datasets. For example, the first column provides the SSI incidence rates per 100 procedures among patients who had colon surgery (3%). You can further indicate the number of procedures in each category to provide more detail.

- **Scale**: Selecting appropriate scale allows readers to visualize the variability between data. In the graph below, readers can easily compare the SSI rates; SSI rates following hysterectomies were nearly double rates after C-sections. A scale of 5 percentage points would not allow a comparison as easily as a scale of 1. Always select the scale that allows better visualization of data.
There are many types of graphs that can be used to show IPC data, including pie charts, bar graphs, and histograms.

**Pie charts** show components of a whole and are commonly used to graphically display discrete data (e.g., proportion of each type of HAI in a health care facility). The primary purpose of a pie chart is to communicate the names and relative sizes of the components (wedges). Figure A-3 allows readers to compare the percentage of CLABSIs in 2016 by the department where the central lines were inserted. The pie chart clearly shows that most of the CLABSIs resulted from central lines inserted in the intensive care unit.

**Bar charts** display data to compare the size and magnitude of differences. For example, the bar chart in Figure A-4 shows data on length of stay for all patients and patients who developed an HAI in three departments at District Hospital.
This chart presents information from three departments in one graph. One can see that the mean hospital stay for patients with an HAI is higher than for those without an HAI. The mean length of stay due to HAIs in the GYN (gynecology/obstetrics) department is longer than in the GI (gastrointestinal) and general surgery departments. Based on this information, the IPC team should work on reducing HAIs for all patients in the hospital by improving IPC practices, conduct a further assessment of HAI cases in the GYN department, and address any specific IPC-related issues.

**Histograms** are used to show how often a value occurs in a given interval in a dataset. They are frequently used to display continuous data. Figure A-5 is a histogram showing transmission of a skin infection during an outbreak in a hospital in Thailand. It illustrates a gradual increase in the number of cases at the beginning of the outbreak, a sharp increase in the second week, and a peak on January 25. The outbreak ended after the ward was closed for 2 days, January 26 and 27.
**Figure A-5. An Outbreak of Hospital-Acquired *Staphylococcus aureus* Skin Infection among Newborns**

Epidemic curve of staphylococcal bullous impetigo cases by date of onset in a district hospital, Nan Province, Thailand, January 2008 (n=30)


**Dashboards**

An additional visual way to share IPC data is with a data dashboard. An IPC dashboard is information presented on a single page showing a variety of measures, such as hand hygiene compliance, SSI rates, CLABSIs, and non-central line-related bloodstream infection (sepsis) rates. The idea comes from a dashboard in a car showing speed, fuel, and temperature gauges all in one place that the driver can quickly see and analyze. Dashboards can be effective tools for communicating IPC data because various measurements and performance indicators can be shown in one place in an easily understandable way (see Figure A-6).
Source: Avi Gadala, Hospital Epidemiology and Infection Control, Johns Hopkins Hospital.
References


Chapter 2: Introduction to Surveillance of Health Care-Associated Infections

Key Topics

- Characteristics and types surveillance for health care-associated infections (HAIs)
- Purposes of conducting surveillance
- Prioritizing surveillance for HAIs
- Designing an HAI surveillance program
- Implementing the program
- Data analysis and feedback
- Performance improvement

Key Terms

- **Benchmark** is a standard or point of reference against which surveillance data can be compared or assessed to determine how well a facility is doing.
- **Community-acquired infection** is an infection that is present or incubating upon presentation at the health care facility or becomes evident on the first or second day of admission. Community-acquired infections may be of great importance and reporting them to the public health authorities may be required. However, for purposes of identifying HAIs, community-acquired infections are excluded from surveillance data.
- **Denominator** is the lower portion of a fraction. In the context of HAI surveillance, it is the population at risk for the infection being observed. Examples of denominators in infection prevention and control (IPC) surveillance are numbers of procedures, patient-days, device-days, admissions, and observations.
- **Device-associated infection** is an infection associated with invasive devices used as part of their care, to treat patients and to help them recover, such as central venous lines, mechanical ventilators, urinary catheters. These infections are often serious, even life-threatening.
- **Health care-associated infection (HAI)** is an infection that occurs in a patient as a result of care in a health care facility and was not present at the time of arrival at the facility. To be considered an HAI, the infection must begin on or after the third day of admission to the health care facility (the day of admission is Day 1) or on the day of or the day after discharge from the facility. The term “health care-associated infection” replaces the formerly used “nosocomial” or “hospital” infection because evidence has shown that these infections can affect patients in any setting where they receive health care.
- **Incidence** is the rate at which new events (e.g., surgical site infections [SSIs] or bloodstream infections [BSIs]) occur in a population for a specific period (e.g., SSIs per 100 procedures or BSIs per 100 births).
- **Indicator** is a quantitative variable that provides information to monitor performance, measure achievement, and determine accountability. A validated indicator is an indicator that accurately measures what it is intended to measure and allows comparison of results.
Surveillance

- **Numerator**, in surveillance, is the number of times an event occurs during a specified time interval. Examples of numerators in IPC surveillance include the number of cases of a specific infection (e.g., SSIs or central line-associated bloodstream infections [CLABSIs]) or the number of occurrences of an event, such as the number of persons who performed hand hygiene.

- **Outcome measure** indicates the results of the performance (or non-performance) of a function or process. It may describe a desirable or undesirable event. Outcome measures used in IPC usually describe undesirable events, such as rates of SSIs or CLABSIs.

- **Prevalence** is the number of existing cases of a particular disease, injury, health condition, or event in a defined population at a given point in time. It includes both new cases and existing cases (e.g., number or patients with HAI present in the hospital today).

- **Process measure** is an indicator that focuses on a process or the steps in a process that lead to a specific outcome. It can be useful to evaluate process measures if they can be linked to an outcome. Process measures are commonly used to evaluate compliance with desired care or support practices or to monitor variation in these practices. Examples of process measures are the proportion of health care workers (HCWs) performing hand hygiene following World Health Organization (WHO) guidelines, or the proportion of women undergoing cesarean section (C-section) who are given an appropriate dose of prophylactic antibiotics.

- **Rate** is an expression of the frequency with which an event (e.g., an infection) occurs in a defined population in a given time period. Rate always includes time as a part of its expression.

- **Risk adjustment** is a statistical process that allows comparison of two outcomes by adjusting for different risks that might affect outcomes. This is done by adjusting for risk factors such as age, body mass index, gender, and other existing conditions that might affect the outcome being measured so that rates from two sources can be compared.

- **Standardized infection ratio** is a summary measurement that compares the number of reported infections among a group of patients to the number of predicted or expected infections, based on a standard population.

- **Surveillance** is the systematic collection, analysis, and interpretation of data on the frequency of disease. It is essential to the planning, implementation, and evaluation of public health practices and the timely dissemination of the data for public health action (prevention and control). For this manual, surveillance is discussed in relation to HAI.

- **Surveillance case definition** is a case definition used for the purpose of surveillance. These definitions are not the same as clinical case definitions as the purpose is not to inform clinical decision-making and treatment but rather to gather information in a consistent and systematic way. Surveillance definitions must be static/standard and consistent in order to measure the same event over time. It is possible to have a patient clinically diagnosed with an infection that does not meet the surveillance definition and vice versa. If definitions are applied consistently, anomalies will balance out in the results.

**Background**

HCWs do not intend patients to suffer any harm in the course of, or as a result of, their care. Providing essential information to staff on HAIs occurring in the areas where they work allows them to explore possible causes and develop strategies to improve IPC practices and prevent HAIs. (See Module 1, Chapter 1, Introduction to Health Care-Associated Infections).
Surveillance has been shown to be a powerful tool to achieve this objective. Bonita et al. (2006) define health surveillance as “the ongoing systematic collection, analysis, and interpretation of health data essential for planning, implementing and evaluating public health activities.”

Surveillance for HAIs is a systematic way to gather information (data) to describe the occurrence and distribution of HAIs. HAI surveillance includes the collection, compilation, analysis, interpretation, and distribution of information about HAIs. Box 2-1 provides examples of how surveillance data can be used to measure patients harm.

Box 2-1. Examples of Surveillance Data Measuring Patient Harm

- 20 out of every 100 patients who undergo a C-section (20%) and 5 out of every 100 patients who undergo an appendectomy (5%) develop an SSI.
- On March 23, 2018, 6 of the 30 patients in the labor and delivery ward have an HAI (prevalence of 20%) compared to 3 of the 30 patients (prevalence of 10%) in similar wards.
- The rate of hospital-acquired bloodstream infection (BSI) (sepsis) in the newborn nursery is 5 per 1,000 patient-days at this health care facility but other health care facilities in the region have a rate of 1 per 1,000 patient-days.

Studies have shown that health care facilities with effective HAI surveillance systems and strong prevention and control programs have reduced occurrence of patient harm from HAI (Ellingson et al. 2014; Haley et al. 1985). However, health care facilities in many low- and middle-income countries do not have systems for HAI surveillance.

According to WHO, 66% of countries do not report HAI surveillance data (WHO 2011). The data that do exist show that limited-resources settings have higher rates of HAI than high-income countries—1 in every 10 patients develops an HAI, which is about double the rate for high-income countries (Rosenthal et al. 2014; WHO 2011). Since surveillance for HAI can be complex, this lack of data is understandable as surveillance requires standardized criteria, diagnostic capability, and expertise to conduct and interpret the results. This chapter provides information for IPC staff to develop surveillance programs appropriate to the available resources.

**Surveillance of Health Care-Associated Infection**

**Characteristics of Effective Surveillance**

In order for surveillance to be effective, it is critical that:

- Surveillance is based upon sound epidemiological and statistical principles (see Chapter 1, Basic Epidemiology and Statistics for Infection Prevention and Control, in this module).
- Data are properly collected and analyzed.
- Information is shared in a timely manner with those who can act to improve IPC practices and the quality of care. Efforts to improve practices and decrease HAI are a critical part of the surveillance plan.
HAI Surveillance

Types of Surveillance

Surveillance activities can be outcome- or process-oriented.

- **Outcome surveillance**: monitoring of specific HAIs (e.g., SSIs, catheter-associated urinary tract infections [CAUTIs], diarrhea), or
- **Process surveillance**: monitoring of patient care practices, including IPC practices (e.g., compliance with hand hygiene, timing of prophylactic antibiotics during surgery, use of aseptic technique for central line insertion).

Surveillance can be continuous or periodic:

- **Continuous**: data are collected continuously on a routine basis, or
- **Periodic**: data are collected at intervals, such as 1 month each quarter or 1 quarter per year.

Surveillance can be active or passive (see Box 2-2):

- **Active surveillance** is the identification of HAIs by trained personnel who proactively look for HAIs using multiple data sources. Active surveillance is conducted by trained staff using standardized case definitions and is more accurate than passive surveillance.
- **Passive surveillance** of HAIs refers to the identification of HAIs by patient care providers, such as physicians or nurses, who may not be formally trained in surveillance and may not consistently use standardized surveillance case definitions to identify HAIs. (Heipel et al. 2007)

**Box 2-2. Examples of Active and Passive Surveillance**

**Active surveillance**

Trained staff conduct rounds on the ward to look for signs and symptoms of BSIs post-childbirth.

Trained staff review wound culture results from the laboratory and medical records of C-section patients for positive wound cultures and signs and symptoms of infection according to the definition to identify SSIs.

**Passive surveillance**

The neonatal intensive care staff report the number of cases of sepsis that occurred last month.

**Purposes of Conducting Surveillance for Health Care-Associated Infections**

Surveillance can help guide IPC activities by providing data on outcomes as well as processes. Surveillance should respond to the facility’s actual needs.

Outcome surveillance helps the IPC team to:

- Determine baseline rates of HAI
- Identify occurrence of infections above the baseline (expected) rates
- Detect and report notifiable diseases to the public health authorities
- Detect and investigate clusters, outbreaks, and exposures, including emerging infectious diseases
Process surveillance helps the IPC team to:

- Observe HCWs’ practices to ensure compliance with policies and best practices
- Provide information to help guide performance improvement activities
- Assess the effectiveness of IPC measures
- Meet the safety standards required by the health department and other regulatory agencies

**Surveillance is valuable for planning allocation of resources** because it can reveal if and where HAIs are occurring as well as the size and causes of the problem. Resources can then be focused on areas with high rates of HAI.

**Surveillance provides data that can guide and influence change** when it is used to calculate rates, percentages, or standardized infection ratios (SIRs). These data can be presented in a way that is easy for key staff to understand and identify trends in order to make patient safety improvements. Key staff may include hospital administrators, supervisors, clinical staff, cleaning staff, disinfection/sterilization staff, and others. (Chapter 1, Basic Epidemiology and Statistics for Infection Prevention and Control, in this module provides detailed information on the generation of key statistics and visual representation of data in IPC.)

**Surveillance can be used to monitor and evaluate improvement efforts.** Performing surveillance before, during, and after efforts to prevent harm and improve patient safety can inform the staff about the effectiveness of their efforts.

**Steps for Conducting Surveillance in a Health Care Facility**

**Prioritize Surveillance Activities**

Depending upon the planned scope of activities, surveillance of HAIs requires: clinical staff time (the larger the effort, the more staff time will be required for data collection, management, and analysis); laboratory diagnosis support (more advanced surveillance systems require higher-quality support to identify organisms causing infections and patterns of resistance to antimicrobials); well-designed data collection tools; and data management (the more complex the surveillance, the more data will be collected and need to be entered and analyzed for the information to be useful).

Surveillance for all types of infections is rarely done in any setting. Prioritizing surveillance activities is essential for effective allocation of resources to maximize the benefits of reducing HAI among patients admitted to health care facilities. This is important in all settings but especially in low- and middle-income settings where resources are scarce. When planning surveillance, priority areas are:

- High-risk areas such as intensive care and postoperative units
- High-risk patient populations such as immune-compromised patients and neonates
- High-risk procedures (varies depending on the scope of the setting)
- Diseases present in the community with potential to rapidly spread through the hospital

**Note:** An effective surveillance program includes the collection and analysis of data so that the data can be shared with key staff to inspire them to fix problems. Without sharing of data, surveillance efforts may be wasted.
HAI Surveillance

While the extent of surveillance activities depends upon available resources, the prioritization and focus for any facility are ideally based on a risk analysis (see Appendix 1-A in Module 11, Chapter 1, Structure and Oversight of Infection Prevention and Control Programs).

To set priorities, the health care facility team should:

- Review available HAI data and prioritize what they want to include in surveillance during the initial stages. Globally, surveillance of HAI focuses on SSIs, CAUTIs, CLABSIs, and ventilator-associated pneumonia (VAP), but other types of HAI may be appropriate.

- If data are limited, carry out an assessment to identify key HAIs in the facility and, based on local needs, decide which HAIs to include in surveillance.

- Start surveillance activities with just one HAI and add other HAIs based on observed priorities and needs.

- Select wards or areas (e.g., intensive care units [ICUs]) with the highest number of HAIs or most serious complications from HAIs.

- Select procedures based on risk of complications as well as number performed. For example, a maternity hospital may choose to begin surveillance with SSIs following C-sections (most frequently performed and high risk of infection) and later add other procedures (e.g., hysterectomy).

Basic surveillance can be conducted without a large infrastructure or many additional resources (see Box 2-3).

**Box 2-3. Examples of Surveillance Activities for Health Care Facilities with Limited Resources**

These examples of surveillance activities are appropriate for facilities that are starting surveillance and those with limited resources. They can help prevent all HAIs.

- Develop a plan to assess whether staff have access to soap and water and towels to dry their hands or alcohol-based handrub. Monitor hand hygiene practices. Use surveillance data to improve compliance (see Module 2, Hand Hygiene).

- Ensure that patient care practices are performed according to the best available evidence (i.e., use Standard Precautions for all patients [see Module 1, Chapter 2, Standard and Transmission-Based Precautions]).

- Ensure adherence to recommended IPC practices, such as sterilization or high-level disinfection of all items that come in contact with normally sterile tissue (see Module 6, Chapter 1, Overview of Processing Surgical Instruments and Medical Devices).

- Monitor compliance with recommended practices for certain high-risk procedures, such as inserting and caring for central venous catheters (see Module 10, Chapter 3, Preventing Intravascular Catheter-Associated Bloodstream Infections).

- Monitor employees’ exposure to infections and needle-stick injuries and use the data to develop plans to reduce exposures.
**Design and Develop a Surveillance Approach**

Choose whether to monitor an outcome or a process measure

Once the specific type of surveillance activities needed by the facility have been prioritized, a determination will need to be made about whether to conduct surveillance on the type of infection (outcome), or on a process designed to prevent that infection, or both.

Select appropriate indicators

It is best to use indicators that have been validated or are commonly used because they will allow results to be compared with those from similar facilities. Examples of indicators used for IPC include:

- HCWs’ compliance with hand hygiene guidelines (the proportion of compliant hand hygiene opportunities)
- The SSI rates following C-sections, per 100 C-sections
- The CAUTI rates per 1,000 catheter-days

Consider benchmarks and goals

Benchmarks are a helpful reference against which a facility’s surveillance data can be compared. Internal benchmarks can be used to compare IPC surveillance data for a given period with earlier data (baseline data). External benchmarks allow a facility to compare its data with those from other facilities, either regionally, nationally, or internationally. (Al-Saed et al. 2013)

Table 2-1 provides a list of organizations that provide HAI rates for benchmarking and their advantages and disadvantages.
Table 2-1. Sources and Advantages and Disadvantages of Recognized Benchmarks

<table>
<thead>
<tr>
<th>Source of Recognized Benchmarks</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>World Health Organization (WHO): <a href="http://www.who.int">www.who.int</a></td>
<td>Includes low-income countries separately, good crude estimates</td>
<td>Results obtained by differing methods and case definitions, not risk-adjusted, limited data available from low-income countries</td>
</tr>
<tr>
<td>Report on the Burden of Endemic Health Care-Associated Infection Worldwide: Clean Care Is Safer Care; pages 14 and 19. <a href="http://apps.who.int/iris/bitstream/10665/80135/1/9789241501507_eng.pdf">http://apps.who.int/iris/bitstream/10665/80135/1/9789241501507_eng.pdf</a></td>
<td>Uses standardized definitions similar to NHSN/CDC, includes under-studied, low-income countries</td>
<td>Lack of non-ICU and SSI data, no risk adjustment, included data may not reflect the respective country</td>
</tr>
<tr>
<td>International Nosocomial Infection Control Consortium (INICC): <a href="http://www.inicc.org">http://www.inicc.org</a></td>
<td>Includes ICU and non-ICUs, uses complex and frequently changing NHSN/CDC definitions, large data set, risk-adjusted</td>
<td>No non-device associated infections</td>
</tr>
<tr>
<td>United States Centers for Disease Control and Prevention (CDC), National Healthcare Safety Network (NHSN): <a href="http://www.cdc.gov/nhsn/about.html">http://www.cdc.gov/nhsn/about.html</a></td>
<td>Large data set, risk-adjusted</td>
<td>Lack of non-ICU data, definitions used not popular outside of European countries</td>
</tr>
</tbody>
</table>


When choosing a benchmark, it is important to ensure that the benchmark is relevant to the setting. Consider using WHO’s low- and middle-income country data (see Table 2-2) or data from the International Nosocomial Infection Control Consortium (INICC). The IPC team should review data from various sources before selecting a benchmark and consider risk adjustment. Health care facilities should aim at achieving HAI rates that are lower than the chosen benchmark.

Table 2-2. Device-Associated HAIs and Device Utilization in Adult Medical-Surgical ICUs

<table>
<thead>
<tr>
<th>WHO Benchmarks</th>
<th>CLABSI</th>
<th>CAUTI</th>
<th>VAP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rates (Range) Per 1,000 central line-days</td>
<td>Rates (Range) Per 1,000 catheter-days</td>
<td>Rates (Range) Per 1,000 ventilator-days</td>
</tr>
<tr>
<td>High-resource countries (1995–2010)*</td>
<td>3.5 (2.8–4.1)</td>
<td>4.1 (3.7–4.6)</td>
<td>7.9 (5.7–10.1)</td>
</tr>
<tr>
<td>Low-resource countries (1995–2010)*</td>
<td>12.2 (10.5–13.9)</td>
<td>8.8 (7.4–10.3)</td>
<td>23.9 (20.7–27.1)</td>
</tr>
</tbody>
</table>

CLABSI—central line-associated bloodstream infection; CAUTI—catheter-associated urinary tract infection (UTI); VAP—ventilator-associated pneumonia

*WHO estimates are from all types of adult ICUs and included both catheter-related and catheter-associated BSIs and UTIs.

*Note*: The eventual goal for all health care facilities should be to achieve zero rates (no infections) for all HAIs and 100% compliance with recommended IPC practices. An interim goal can be to achieve rates lower than the chosen benchmark.

Adapted from: WHO 2011.
Define the Denominator

To fully describe the occurrence of HAI, qualify its importance, interpret variations, make comparisons, and calculate infection rates, the number of total possible events is needed (WHO 2002). This is the denominator. Chapter 1, Basic Epidemiology and Statistics for Infection Prevention and Control, in this module provides detailed information on the importance of the denominator. In HAI surveillance, use of the standard HAI denominators will allow rates to be compared with other facility rates.

Types of denominators (incidence surveillance)

- **Patient-days at risk**: The number of patients present on the ward each day, added together (usually added for each month, quarter, or year)
- **Device-days**: The number of patients with a device on the ward each day (e.g., urinary catheter), added together (usually added for each month, quarter, or year)
- **Procedures**: The number of cases of a particular type of surgery performed (e.g., C-section)
- **Event**: The number of occurrences of a certain type of event (e.g., live birth, admission to the facility, patients treated at the HIV clinic)

Denominator examples

- **SSI following C-section**: All pregnant women who undergo a C-section in the health care facility. This can be calculated on an ongoing basis if it is continuous surveillance or for the time period of interest if it is periodic surveillance. It can be done retrospectively from the review of an operating theater register or prospectively by keeping/collecting data on each pregnant woman undergoing a C-section. The same approach can be followed to list the denominator for SSIs following any surgical procedure.

- **CAUTI**: The number of device-days with a urinary catheter. Device-days for CAUTI can be calculated by counting the number of patients in either a ward or the whole health care facility who have an indwelling catheter on that day, counted at a fixed time each day, either on a routine basis or for a specific time period of interest, and maintaining a denominator list. Rather than the number of patients who have an indwelling urinary catheter inserted, the number of days patients have a device (the urinary catheter) is used as the denominator to better calculate the time patients are exposed to the risk of catheters. It is a more sensitive measure.

- **BSI (sepsis)**: The number of patient-days at risk of contracting a BSI. Patient-days for BSI can be calculated by counting every infant in the nursery at about the same time each day and entering into a list either a daily manual count or a census number from the medical records. This will give the number of patient-days over a desired time frame. This information is needed because infants are at risk for health care-associated sepsis every day they are in the hospital, not just at the single time when they are admitted.

Define the Numerator by Using a Case Definition

The numerator for HAI surveillance is the number of times the infection of interest (e.g., SSI) occurs among the population at risk during a specific time interval (see Chapter 1, Basic Epidemiology and Statistics for Infection Prevention and Control, in this module for detailed information on the numerator). Numerator data are collected by using a written, standardized surveillance case definition to determine which cases are included and which are not. A surveillance case definition is a set of uniform criteria used to define a disease for public health surveillance.
HAI Surveillance

- Use standard case definitions for HAI where possible.
- Utilize country-specific surveillance case definitions where they exist so results can be benchmarked with other local facilities.
- The CDC National Healthcare Safety Network (NHSN) has developed detailed case definitions, which are regularly updated. For the most up-to-date HAI surveillance case definition criteria, see: https://www.cdc.gov/nhsn/pdfs/pscmanual/pcsmanual_current.pdf.
- Lab-based components of surveillance case definitions may not be achievable in limited-resource settings and so adaptation to local needs and diagnostic and lab capacity may be needed. Examples from WHO (2002) include:
  - **Surgical site infection**: Any purulent discharge, abscess, or spreading cellulitis at the surgical site during the month after the operation
  - **Intravascular catheter infection**: Inflammation, lymphangitis, or purulent discharge at the insertion site of the intravascular catheter

Irrespective of the definitions you choose, they must be applied in the same manner to each case to ensure consistency in the numerator data collection and to calculate rates over time and for comparison. (APIC 2014; Rosenthal 2014 et al.; WHO 2002; WHO 2009)

**Design and Develop the Process for Monitoring the Chosen Event**

**Time period (incidence surveillance)**

Determine the time period for data collection, which could be a month, a quarter (periodic incidence surveillance), or continuously (incidence surveillance). Based on available resources, needs, and scope, the surveillance could be continuous (ongoing as a routine activity) or periodic (occurring for a specific period of time on a regular basis). See Box 2-4 for examples.

**Box 2-4. Examples of Surveillance Time Periods**

**Continuous monitoring**—surveillance is ongoing throughout the time frame:
- All patients who had a C-section for surgical site infection
- All patients with a central venous catheter for bloodstream infection
- All babies on the neonatal intensive care unit

**Periodic monitoring**—surveillance occurs at predetermined intermittent intervals to manage resources:
- All patients who had a C-section for SSI for 3 months (part of each year)
- All patients with a central venous catheter for bloodstream infection for 1 month in every 3
- All babies admitted to the neonatal intensive care unit for BSI (sepsis) for 6 months of the year
Case identification

Determine if potential cases in the facility are best identified based on signs and symptoms, laboratory results, or a combination of these.

- Laboratory-based case finding is often the easiest method: Potential cases are triggered by a positive lab result from clinical or surveillance specimens, for example, review of all blood or wound cultures for positive results. However, this may not be feasible in settings with limited microbiology capacity or where cultures are not reliably taken when infection is suspected.

- Finding potential cases by searching for clinical signs and symptoms of infection can be more time-consuming: Potential cases are identified during daily rounds, discussions with the HCWs caring for the patients, or review of the medical records. This may be the best method in settings where microbiology data are often lacking.

Prospective or retrospective surveillance

Determine if the situation at the facility is best suited to prospective or retrospective surveillance methods based on the quality of existing data and available resources.

- Prospective surveillance data are being collected in the present time, following the patients through their hospital course, looking for potential HAIs. It can be more reliable than other methods if documentation is poor but requires more resources because all patients need to be followed in order to identify HAIs.

- Retrospective surveillance reviews patient data once potential infections been identified (e.g., by positive culture). Retrospective surveillance requires fewer resources but will not be effective if medical record documentation is less than comprehensive.

Number of observations (for process measure surveillance)

Based on the process selected for surveillance and the time allocated for data collection, the team will need to determine the number of observations to be made. For example, a health care facility may decide to monitor hand hygiene compliance on each ward for 20 minutes, once each week, aiming for 40 observations every week. Or the team may decide to monitor the operating theater staff’s use of proper personal protective equipment once every month, aiming for 25 observations per month. The larger the number of observations, the more reliable the results will be. The number of observations will also depend upon available resources. These examples are not relevant for outcome surveillance, in which all events should be captured during the predetermined time frame.

Data collection plan

An ideal data collection plan will include details on the following:

- **Data elements**: Data elements will depend upon the outcome or process being monitored. Collect only those data elements that will facilitate analysis and decision-making for interventions. It may require a short trial to be sure that all needed elements are collected.
  
  - For outcome surveillance, data elements for patients with HAI should include, at a minimum, the patient identifier, admission date, device insertion/procedure date, elements of the case definition (signs, symptoms, results, and diagnoses) (to determine whether the case definition has been met) and date of infection. Other data may also be appropriate (such as demographic information and specific risk factors) but these will be determined by the type of HAI and resources available to gather and manage these data. (See the HAI data collection forms in Appendix 2-A.)
For process surveillance, data elements depend upon the process being monitored.

- **Data collection tools**: Prepare or adapt data collection tools for the numerator and denominator for the HAI or the IPC practice selected for surveillance. There are standardized data collection tools available for most common HAIs—SSI, BSI/CLABSI, UTI/CAUTI, and hospital-acquired pneumonia (HAP)/VAP. Depending upon the scope and the need, the facility should adapt available tools for collecting data for both the numerator and denominator. (See Chapter 2, Introduction to Surveillance of Health Care-Associated Infections, in this module.)

- **Data collectors**: Appropriate persons to collect data should be selected based on the type of surveillance and frequency of data collection. IPC staff often collect surveillance data; however, data collectors can be clinicians specially assigned for data collection or can be health care providers in the facility. Data collectors should be trained in correctly completing the data collection forms in a standardized manner.

- **Data collection methods**: Data collection methods will depend upon several factors and the decisions made about type, frequency, and the outcomes or processes included in surveillance. Methods can be paper-based or electronic. Data can be collected by regularly visiting the site or by reviewing paper or electronic records.

- **Data sources**: These include records, reports, registers, and logbooks where specific data can be found. As an example, chart reviews of patients’ cases can provide information on numerators, and operating theater case records or daily census reports can provide information on denominators.

- **Data management**: This is a method of receiving and collating data collection forms. The persons responsible will need to be identified and assigned the tasks. Forms should be reviewed to ensure completeness and accuracy. There should be a database into which data will be entered to allow data analysis and reporting. (This could be a simple, paper-based template, logbook, or a Microsoft Excel-based template, or more advanced statistical software.) If data are collected on paper forms, decide if the data then need to be entered into a computerized database. Procedures for filing and storing forms should be developed, whether electronically or manually. At minimum a logbook or line list should be kept of infections (numerator) and denominator so rates can be calculated.

- **Data sharing**: Develop a plan and decide who will collate data, prepare reports, and share data with relevant parties. Chapter 1, Basic Epidemiology and Statistics for Infection Prevention and Control, in this module contains a detailed section on data sharing with examples and instructions on how to prepare tables, graphs, and charts.

(APIC 2014; CDC 2006)

**Implement Surveillance Activities**

Once planning for surveillance is complete, the health care facility should be ready to implement surveillance activities.

Data collection is a key component of surveillance of HAI or IPC processes. Carry out data collection using standardized data collection tools for the numerator and denominator. Collect data retrospectively or prospectively, as planned.

For **outcome surveillance**:

- Ensure that all cases that qualify for the numerator and all patients that qualify as the at-risk population (denominator) are appropriately recorded and reviewed. Continue data collection, or if periodic surveillance has been planned, stop when the time period ends (month, quarter, etc.).
Enter all information from the completed tools into the database on a regular basis to avoid loss of information on completed forms. If data are collected electronically, ensure regular backup of data on two different devices.

For **process surveillance**:
- Complete the data collection forms following the plan and data collection method. Process surveillance may include direct observation of clinical practices for data collection (e.g., observing hand hygiene monitoring) or a review of the records could also be used if such records are maintained (e.g., monitoring correct timing of dressing changes). Ensure that the number of planned observations are made.

**Analyze and Report Data**

After the data are collected and entered into the database, collate, clean, and review individual data for any obvious errors and outliers. Conduct data analysis using a software program or a simple calculator and statistical formulas to derive mean, median, mode, percentage, proportion, or incidence density rates. The data should be cleaned (checking data and correcting or removing errors) and analyzed to calculate rates and prepared for sharing with key personnel as laid out in the plan.

A surveillance report may be a written document or a presentation and at a minimum should contain:
- Description of the surveillance activity (e.g., SSI in women undergoing C-section in the health care facility, CLABSI from date to date, compliance with surgical attire guidelines before entering the operating theater for surgery)
- The goals and objectives of performing surveillance
- Description of outcomes and processes selected for surveillance and the standard surveillance case definitions used
- Information on the numerator and denominator as absolute numbers, as well as other descriptive data, such as mean, median, mode, etc. For example:
  - CLABSI: Of the 3,000 device-days (number of days in which patients at the facility had a central line in place—denominator) during the year, there were 9 cases of CLABSI (numerator)
- Rates, percentages, and comparisons with the chosen benchmark (e.g., SIR)
- Graphs and/or tables describing the findings that are easy to understand
- A description of recommended actions based on the findings of the surveillance data analysis (see Module 10, Prevention of Health Care-Associated Infections).

Share the report with all stakeholders; HCWs, the management team, and other stakeholders can help design interventions according to the surveillance plan. Surveillance findings should be shared with the HCWs during staff meetings on a routine basis. Keep the report brief and focus on key findings and messages for improvement.

**Initiate Quality Improvement Activities**

After reviewing surveillance data and reports, determine what performance improvement activities should be undertaken. Use process measure surveillance data to identify gaps in practice and guide performance improvement activities. Process and outcome surveillance can be described as a circular process (see Figure 2-1), which is part of improving the quality of patient care, in this case by preventing
infections. Quality improvement should be an ongoing activity that uses data to inform interventions to improve patient safety (see Module 11, Chapter 1, Structure and Oversight of Infection Prevention and Control Programs, section on Implementing Strategies for Quality Improvement in IPC). (WHO 2002)

Figure 2-1. Surveillance Process

Adapted from: Deming 1993; WHO 2002.

For example: The health care facility IPC team shares the findings of the process measure surveillance for compliance with hand hygiene after removing gloves. While the target was 85% compliance, the actual compliance was 45%. The IPC team carries out the analysis to find out the cause for the lack of compliance. As a result of the findings, the health care facility manager places alcohol-based handrub stations close to the points of care so that HCWs can perform hand hygiene immediately after removing gloves, after patient care, and before moving to the next patient. Performance after the changes is measured, and hand hygiene after removing gloves is now 70%. The process is repeated.

Tips for Carrying Out Outcome Surveillance

- Make institutional decisions about implementing surveillance of HAIs in the facility based on a facility IPC risk assessment (see Module 11, Appendix 1-A).
- Establish a surveillance technical group, which could be a subgroup within the IPC team.
- Follow national guidelines on surveillance of HAIs, if one is available. If national guidelines are not available, use international guidelines.
- Use standardized case definitions.
- Review and adapt data collection tools, as appropriate.
- Decide on approaches for surveillance (e.g., active vs. passive, outcome vs. process).
- Train key staff in surveillance of HAIs.
- Orient all clinical staff on surveillance of HAIs and their roles and responsibilities.
- Allocate resources for data collection, data entry, data compilation, data analysis, and reporting.
- Conduct surveillance.
- Carry out detailed analysis of the findings and identify the gaps. Perform gap analysis to identify the root causes of any gaps.
- Organize periodic meetings to review the findings.
- Design and develop interventions to changes practices and processes.
- Monitor compliance with interventions.

**Summary**

Surveillance is an effective tool that can be used to improve IPC practices and decrease HAIs. However, it can be labor-intensive and utilizes resources, so a thoughtful approach is needed when developing a surveillance plan. Basic surveillance can be conducted without a large infrastructure or many resources. For facilities developing a surveillance program for the first time, start slowly, gain experience, and expand as problems are identified and as resources allow. Surveillance should start with an infection risk assessment. Surveillance is only truly beneficial when the results are used to inform actions that will make patients safer.
### Appendix 2-A. Sample Surveillance Data Collection Forms for Device-Associated Health Care-Associated Infection

Tables A-1 and A-2 are examples of data collection forms for surveillance of device-associated health care-associated infections (HAIs). Countries may have their own forms based on their case definitions and data elements identified for tracking HAIs.

#### Table A-1. Numerator Data Collection Form for Urinary Tract Infections and Catheter-Associated Urinary Tract Infections

<table>
<thead>
<tr>
<th>Facility Name:</th>
<th>Patient Name (Last):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location (Ward or Unit):</td>
<td>Patient Name (First):</td>
</tr>
<tr>
<td>Gender (M or F):</td>
<td>Date of Birth: (dd/mm/yy):</td>
</tr>
<tr>
<td>Date of Admission (dd/mm/yy):</td>
<td>Date of UTI (dd/mm/yy):</td>
</tr>
<tr>
<td>Date of urinary catheterization (dd/mm/yy):</td>
<td></td>
</tr>
</tbody>
</table>

**Risk Factors**

<table>
<thead>
<tr>
<th>Urinary Catheter Status</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>In place:</td>
<td>Removed: Urinary catheter in place &gt; 2 days but removed the day before the date of UTI</td>
</tr>
<tr>
<td>Urinary catheter in place &gt; 2 days on the date of UTI</td>
<td></td>
</tr>
<tr>
<td>Ward or unit where device was inserted:</td>
<td>Date of device insertion (dd/mm/yy):</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Event Details**

- Symptomatic UTI (SUTI)
- Asymptomatic bacteremic UTI (ABUTI)
- Catheter-associated UTI
### Specify Criteria Used (Check all that apply)

#### Signs and Symptoms

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Any patient</th>
<th>≤ 1 year old</th>
</tr>
</thead>
<tbody>
<tr>
<td>____ Fever</td>
<td></td>
<td></td>
</tr>
<tr>
<td>____ Frequency*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>____ Pain or tenderness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>____ Acute pain, swelling, or tenderness of testes, epididymis, or prostate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>____ Suprapubic tenderness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>____ Costovertebral angle pain or tenderness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>____ Frequency*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>____ Dysuria*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>____ Abscess</td>
<td></td>
<td></td>
</tr>
<tr>
<td>____ Apnea</td>
<td></td>
<td></td>
</tr>
<tr>
<td>____ Acute pain, swelling, or tenderness of testes, epididymis, or prostate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>____ Suprapubic tenderness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>____ Costovertebral angle pain or tenderness</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Laboratory

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Any patient</th>
<th>≤ 1 year old</th>
</tr>
</thead>
<tbody>
<tr>
<td>____ Fever</td>
<td></td>
<td></td>
</tr>
<tr>
<td>____ Hypothermia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>____ Frequency*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>____ Dysuria*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>____ Abscess</td>
<td></td>
<td></td>
</tr>
<tr>
<td>____ Apnea</td>
<td></td>
<td></td>
</tr>
<tr>
<td>____ Acute pain, swelling, or tenderness of testes, epididymis, or prostate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>____ Suprapubic tenderness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>____ Costovertebral angle pain or tenderness</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Secondary bloodstream infection: Yes ____ No ____

#### Died: Yes ____ No ____

#### UTI contributed to death: Yes ____ No ____

#### Pathogen identified: Yes ____ No ____

#### Discharge date (dd/mm/yy):

#### Types of Pathogens

<table>
<thead>
<tr>
<th>Pathogens</th>
<th>Any patient</th>
<th>≤ 1 year old</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gram positive organisms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Staphylococcus coagulate negative:</td>
<td>____ Y ____ N</td>
<td></td>
</tr>
<tr>
<td>S. aureus:</td>
<td>____ Y ____ N</td>
<td></td>
</tr>
<tr>
<td>Enterococcus faecium:</td>
<td>____ Y ____ N</td>
<td></td>
</tr>
<tr>
<td>E. faecalis:</td>
<td>____ Y ____ N</td>
<td></td>
</tr>
<tr>
<td>Enterococcus spp:</td>
<td>____ Y ____ N</td>
<td></td>
</tr>
<tr>
<td>Gram-negative organisms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acinetobacter:</td>
<td>____ Y ____ N</td>
<td></td>
</tr>
<tr>
<td>Escherichia coli:</td>
<td>____ Y ____ N</td>
<td></td>
</tr>
<tr>
<td>Enterobacter:</td>
<td>____ Y ____ N</td>
<td></td>
</tr>
<tr>
<td>Klebsiella pneumoniae:</td>
<td>____ Y ____ N</td>
<td></td>
</tr>
<tr>
<td>K. oxytoca:</td>
<td>____ Y ____ N</td>
<td></td>
</tr>
<tr>
<td>P. aeruginosa:</td>
<td>____ Y ____ N</td>
<td></td>
</tr>
<tr>
<td>Other organisms</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Not applicable in patients with indwelling catheters*
### Instructions for Completion of Numerator Data Collection Form for CAUTI Surveillance

<table>
<thead>
<tr>
<th>Data Field</th>
<th>Instructions for data collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facility name</td>
<td>Enter the name of the facility.</td>
</tr>
<tr>
<td>Location (ward or unit)</td>
<td>Enter the name of the ward where patient was admitted. Use the current system of identifying wards (medical, surgical, ob/gyn, pediatric, etc.).</td>
</tr>
<tr>
<td>Patient name: First</td>
<td>Enter first name and middle names of the patient.</td>
</tr>
<tr>
<td>Patient name: Last</td>
<td>Enter patient’s last name or family name.</td>
</tr>
<tr>
<td>Gender</td>
<td>Check appropriate field to indicate patient’s gender.</td>
</tr>
<tr>
<td>Date of birth</td>
<td>If available, enter patient’s birth date in dd/mm/yy format. At a minimum, enter the birth year of the patient.</td>
</tr>
<tr>
<td>Date of admission</td>
<td>Date on which patient was admitted in the health care facility for treatment. If patient was kept in the health care facility for observation before being admitted, the date of admission will be the date when observation started.</td>
</tr>
</tbody>
</table>
| Date of UTI               | This is the date when the first element used to meet the UTI criterion occurred for the first time during the infection window period. 
**Note:** If the device has been pulled on the first day of the month in a location where there are no other device-days in that month, and the device-associated infection develops after the device is pulled, use the last day of the previous month as the date of UTI. |
| Date of urinary catheterization | dd/mm/yy Enter the date of inserting indwelling urinary catheter in dd/mm/yy format. |

### Risk Factors: Urinary Catheter Status

<table>
<thead>
<tr>
<th>In place</th>
<th>Enter √ if urinary catheter was in place &gt; 2 days on the date of UT, otherwise enter X.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removed</td>
<td>Enter √ if urinary catheter was in place &gt; 2 days but removed the day before the date of UTI, otherwise enter X.</td>
</tr>
<tr>
<td>Neither</td>
<td>Enter √ if catheter was neither in place nor removed; otherwise enter X.</td>
</tr>
</tbody>
</table>

### Event details:

<table>
<thead>
<tr>
<th>Specific event</th>
<th>Check either symptomatic UTI, asymptomatic bacteremic UTI, or urinary system infection (USI) for specific event type you are reporting. Any of these three situations qualifies as CAUTI when it is reported.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific criteria used</td>
<td>Required. Check each of the elements of the criteria that were used to identify the specific type of UTI being reported.</td>
</tr>
<tr>
<td>Secondary BSI</td>
<td>Required. Check √ if there is a bloodstream infection (BSI) identified related to UTI; otherwise check X.</td>
</tr>
</tbody>
</table>

### Event detail:

<table>
<thead>
<tr>
<th>Died</th>
<th>Check √ if patient died during the hospitalization; otherwise check X.</th>
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</thead>
<tbody>
<tr>
<td>UTI contributed to death</td>
<td>If patient died, check √ if evidence is available that UTI contributed to death (cause of death, autopsy report, etc.); otherwise check X.</td>
</tr>
</tbody>
</table>

### Event detail:

<table>
<thead>
<tr>
<th>Discharge date</th>
<th>Enter date patient is discharged from facility using dd/mm/yy format.</th>
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</thead>
<tbody>
<tr>
<td>Pathogen identified</td>
<td>Enter √ if a pathogen was identified, X otherwise. If √, specify the pathogens identified.</td>
</tr>
</tbody>
</table>

### Types of pathogens identified

Enter √ in space before Y to indicate if a bacterium in question was identified, otherwise enter √ in space before N.

<table>
<thead>
<tr>
<th>Date</th>
<th># of Patients</th>
<th># of Patients with 1 or More Central Lines</th>
<th># of Patients with Urinary Catheters</th>
<th># of Patients on Mechanical Ventilators</th>
</tr>
</thead>
<tbody>
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<td>1.</td>
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<td>30.</td>
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<tr>
<td>31.</td>
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</tr>
<tr>
<td>TOTAL</td>
<td>Patient Days</td>
<td>Central Line-Days</td>
<td>Urinary Catheter-Days</td>
<td>Mechanical Ventilator-Days</td>
</tr>
</tbody>
</table>
Instructions
Data collection for denominator of device-associated HAIs includes CLABSI, CAUTI, and VAP. Enter your facility name and the location (i.e., ward) where the surveillance activities are carried out. Enter the month, and year. Collect data around the same time every day that you collect data.

- **In the date column**, the dates are numbered starting with 1. Start entering information from the day of the month on which data are being collected, e.g., if it is the 15th of a month, start entering data with the number 15.

- **In the # of patients column**: Enter the number of patients on the ward that day at the time of collecting data. Make sure that you collect this information around the same time every day.

- **In the # of patients with 1 or more central lines column**: Do the head count of patients with 1 or more central lines. Make sure that you collect this information around the same time every day.

- **In the # of patients with indwelling urinary catheters column**: Do the head count of patients with 1 or more indwelling urinary catheters. Make sure that you collect this information around the same time every day.

- **In the # of patients on mechanical ventilators column**: Do the head count of patients with mechanical ventilators in place. Make sure that you collect this information around the same time every day.
References


Rosenthal VD. HAI Rates, Length of Stay, Mortality, Microorganism Profile, and Bacterial Resistance in ICU. Data by Country: Findings of INICC Members. 


Chapter 3: Investigation of Outbreaks of Health Care-Associated Infections

Key Topics

- When to suspect an outbreak
- Key steps for responding to an outbreak of a health care-associated infection (HAI)
- How to investigate infection prevention and control (IPC) practices in response to an outbreak
- Important outbreak investigation skills including developing a case definition, making a line list, and creating an epidemic curve
- Common mistakes in outbreak investigations

Key Terms

- **Case definition** is a set of uniform criteria used to define a disease for public health surveillance.
- **Case finding** is a method of identifying patients with HAIs through a combination of reviewing medical records, asking questions directed to patients or health care workers (HCWs), and checking laboratory, imaging, or other relevant data, if available.
- A confirmed case is a case that fits the case definition and is established as a true case of the disease, typically confirmed by laboratory test.
- **Environmental sampling** is the collection of samples from the health care environment or equipment (rather than from humans) that are cultured for microorganisms.
- **Epidemic curve** is a type of graph that plots the cases in an outbreak based on the time of onset of illness.
- Health care-associated infection (HAI) is an infection that occurs in a patient as a result of care at a health care facility and was not present at the time of arrival at the facility. To be considered an HAI, the infection must begin on or after the third day of admission to the health care facility (the day of admission is Day 1) or on the day of or the day after discharge from the facility. The term “health care-associated infection” replaces the formerly used “nosocomial” or “hospital” infection because evidence has shown that these infections can affect patients in any setting where they receive health care.
- Health care-associated infection outbreak is the occurrence of an HAI or adverse events in excess of what would normally be expected.
- **Line list** is a table of suspected and confirmed cases in which each case is listed with the associated date, characteristics, and risk factors.
- **Literature review** is a search for reports summarizing outbreak investigations published in the literature (journals), which will help identify possible sources and insight into optimal investigative methodology.
- **Outbreak investigation** is the process of using epidemiology and other methods to search for the cause and identify likely contributing factors of an outbreak. It also includes implementations of measures that stop or reduce the risk for the continual spread and future occurrences of disease.
Investigating Outbreaks

- **Pseudo-outbreak** is a cluster or an increased number of positive tests for which the results do not correlate with actual infections in patients. Causes include microbiology process errors, surveillance artifacts, and contaminated products, environment, or lab processes causing false positives.

- **Surveillance** is the systematic collection, analysis, and interpretation of data essential to the planning, implementation, and evaluation of public health practice, and the timely dissemination of this information for public health action.

- **Suspected cases** are cases that fit the case definition but are not yet established as true cases of the disease, typically lacking confirmation by laboratory test.

**Background**

An HAI outbreak is an unusual or unexpected increase of cases of a known HAI or the emergence of a new infection (WHO 2002). Despite best efforts to prevent them, outbreaks of HAIs can occur in any health care setting and pose a threat to patients and staff.

An outbreak should be suspected when:

- HAIs or adverse events occur above the baseline rate,

- An unusual organism is identified, or

- An adverse event occurs.

When an HAI outbreak occurs, the role of an IPC program is to identify and interrupt the process or practice responsible for transmission as quickly as possible to minimize the risk to patients, staff, and the reputation of the facility. (APIC 2014; WHO 2002)

**Overview of HAI Outbreaks: Sources, Causes, Locations, and Timing**

Outbreaks often have multiple causes, but almost all HAI outbreaks are due to one or more of the following causes:

- Lapses in IPC or clinical practices

- Colonization or infection of HCWs

- Defects in a product or device

- Contamination of a product or device:
  - At the time of production (intrinsic contamination), or
  - During use (extrinsic contamination).

- Visitors who are infected or colonized with an infectious disease

(APIC 2014)

In many instances, the cause of the outbreak can be easily identified by looking for a common source, patient care practice, or non-compliance with recommended practices. The outbreak can usually be resolved by removing the source or improving patient care practices. Some outbreaks, however, can be very complex, and the source or practice contributing to the outbreak may be difficult to identify. These outbreaks may require the assistance of epidemiologists, national or international (e.g., Ministry of Health, World Health Organization [WHO], or Centers for Disease Control and Prevention [CDC]) experts, and the local health department.
Sometimes, but not always, the microorganism responsible for the outbreak can be identified. Some microorganisms are prone to cause outbreaks in health care facilities. Tables 3-1 and 3-2 show common types of infections and pathogens involved in HAI outbreaks.

Some outbreaks are recognized while patients are still in the hospital, but they can also occur after the patient has left the health care setting (e.g., a group of surgical site infections caused by group B streptococcus that develop once the patient is home). An outbreak can also occur in the outpatient setting (e.g., hepatitis B in dialysis patients or a multidrug-resistant, Gram-negative organism in endoscopy patients). Outbreaks occurring after patients have left the inpatient setting are often more difficult to identify than outbreaks occurring in the hospital.

### Table 3-1. Most Common Types of HAI Outbreak by Infection Site

<table>
<thead>
<tr>
<th>Site of Infection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bloodstream</td>
</tr>
<tr>
<td>Surgical wound</td>
</tr>
<tr>
<td>Pulmonary</td>
</tr>
<tr>
<td>Gastrointestinal</td>
</tr>
<tr>
<td>Urinary tract</td>
</tr>
<tr>
<td>Central nervous system</td>
</tr>
<tr>
<td>Liver</td>
</tr>
</tbody>
</table>

### Table 3-2. Most Common Pathogens Involved in Health Care-Associated Outbreaks Investigated by CDC during 1980–2005

<table>
<thead>
<tr>
<th>Pathogen</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Staphylococcus aureus</em></td>
</tr>
<tr>
<td><em>Streptococcus</em> species</td>
</tr>
<tr>
<td><em>Escherichia coli</em></td>
</tr>
<tr>
<td><em>Serratia marcescens</em></td>
</tr>
<tr>
<td>Coagulase-negative staphylococcus</td>
</tr>
<tr>
<td><em>Salmonella</em> species</td>
</tr>
<tr>
<td><em>Enterococcus</em> species</td>
</tr>
<tr>
<td>Herpes virus</td>
</tr>
<tr>
<td><em>Pseudomonas</em> species</td>
</tr>
<tr>
<td><em>Candida</em> species</td>
</tr>
<tr>
<td><em>Enterobacter</em> species</td>
</tr>
<tr>
<td><em>Aspergillus</em> species</td>
</tr>
<tr>
<td><em>Klebsiella pneumoniae</em></td>
</tr>
<tr>
<td><em>Mycobacterium</em> species</td>
</tr>
<tr>
<td><em>Proteus</em> species</td>
</tr>
<tr>
<td>Other Gram-negative</td>
</tr>
</tbody>
</table>

Source: CDC 2015.
Outbreak Investigation

When an outbreak is identified, an investigation should be conducted to assess:

- The source(s),
- The pathogen,
- The host, and
- The mode of transmission.

Modification of one or more of these factors will end the outbreak and help prevent similar outbreaks in the future (APIC 2014). Outbreak control measures will vary depending on the causes of the outbreak, but often include combinations of improvements in patient care and improvement in IPC practices, including Standard Precautions and Transmission-Based Precautions (WHO 2002).

Key Steps in an Outbreak Investigation

Outbreak investigations should be conducted in a standardized manner, following key steps (see Figure 3-1). It is important to know that during a real-life outbreak situation, many of these steps must be implemented at the same time, in a different order, or repeated.

Figure 3-1. Steps in an Outbreak Investigation

| 1. Recognize Potential Outbreak |
| 2. Confirm Presence of Outbreak |
| 3. Alert Key Individuals |
| 4. Perform Lit. Review to Identify Similar |
| 5. Establish a Preliminary Case Definition |
| 6. Develop Method for Case Findings |
| 7. Confirm Diagnosis |
| 8. Prepare Initial Line List and Epidemic Curve |
| 9. Implement Initial Control Measures |
| 10. Identify Potentially Implicated Health |
| 11. Consider Environmental Sampling |
| 12. Additional Steps |
Recognize a potential outbreak

A potential outbreak may be identified by nurses, physicians, microbiologists, health departments, or by a surveillance system (WHO 2002). Many outbreaks are first recognized by front-line HCWs and then brought to the attention of IPC staff who investigate the outbreak.

Confirm presence of an outbreak

Before proceeding with an investigation, it is important to be sure that what appears to be a new or increased number of cases is actually an outbreak. The number of cases should be compared with the number of cases during a previous period (e.g., previous month) and with the number of cases at the same time the previous year. (WHO 2002)

Pseudo-outbreaks occur when there is a cluster or an increased number of positive tests identified but these results:

- Do not correlate with clinical findings. Patients are not showing signs and symptoms of infection. This may occur in the case of contamination of samples or non-symptomatic colonization of patients.
- Are caused by a change in the surveillance system resulting in misclassification of non-infected cases as infection or identification of cases that were always present but previously missed by surveillance.
- Are caused by improvement or lapses in laboratory methods. The lab may start using a more sensitive test, resulting in more positive cases, or there may be contamination of the sample in the lab.

Common causes of pseudo-outbreaks include microbiology process errors, surveillance artifacts, and contaminated products/environment/lab processes causing false positives. (Archibald and Jarvis 2011)

The example in Box 3-1 demonstrates the importance of confirming the presence of a true outbreak as one of the first steps in an outbreak investigation. In this example, the investigators were able to determine that presence of Mycobacterium gordonae in the respiratory samples did represent infections in patients but the organism was being introduced during collection of samples.

Box 3-1. Example from the Field: Confirming the Presence of a True Outbreak

A hospital in Croatia identified an increase in the number of respiratory samples positive for Mycobacterium gordonae in 2009. An outbreak investigation revealed that the samples were being contaminated with M. gordonae from tap water during collection. Guidelines for correct sputum collection were issued. (Zlojtro et al. 2015)

Alert key individuals

It is important to make supervisors and hospital leadership aware of the presence of an outbreak situation so that resources can be made available and communication with staff and the community can be managed. In addition, the microbiology laboratory and staff working in the area where the outbreak is occurring should be alerted to look out for new cases, and to collect and save the appropriate samples for the investigation. (APIC 2014, WHO 2002)
Investigating Outbreaks

The example in Box 3-2 demonstrates how alerting key individuals in the hospital was essential to halting this outbreak of health care-associated Ebola Virus Disease. Resources were made available in the hospital and community and from public health authorities to assist with contact tracing, communicating with the public, processing samples, implementing measures to halt the outbreak, and reinforcing IPC practices.

Box 3-2. Example from the Field: Alerting Key Individuals in the Facility of the Presence of an Outbreak

When health care-associated Ebola Virus Disease was identified in a United States hospital, investigators worked with leadership, hospital staff, community members, and public health authorities to identify/isolate contacts, communicate with the public, process samples, detect transmission methods, implement measures to halt the outbreak (screening and adequate isolation/Transmission-Based Precautions), and reinforce IPC practices (training in use of personal protective equipment). The outbreak was halted through prompt identification and evaluation of potential cases and meticulous IPC practices.

Perform a literature review to identify similar situations

Literature reviews help identify possible sources of the outbreak by answering the question: Where has the organism/problem been found previously? A literature review can also guide the investigators in where and how to look for the cause and provide strategies to stop the outbreak. The following resources may be of help to those in limited-resource settings:

- Worldwide Database for Nosocomial Outbreaks (www.outbreak-database.com)
- US Centers for Disease Control and Prevention (CDC) (www.cdc.gov/) provides an abundance of information ranging from current outbreaks and immunizations to disease-specific subject matter.

Establish a preliminary case definition

Case definitions must include:

- Time,
- Place,
- Specific biological and/or clinical criteria, and
- Differentiation between infection and colonization/chronic disease.
  (WHO 2002)

A case definition will likely change as more information becomes available during the investigation.

The example in Box 3-3 shows a case definition that was developed by the investigators of an outbreak of HIV in a hemodialysis unit. The elements of time, place, biological criteria, and differentiation between new infection and chronic disease can be clearly identified. For more details on creating a case definition, see Chapter 2, Introduction to Surveillance of Health Care-Associated Infections, in this module.
Box 3-3. Example from the Field: Developing a Case Definition

Three cases of new HIV infection among hemodialysis patients at a hemodialysis unit in Saudi Arabia were investigated to determine if there was an HAI outbreak. The investigators developed the following case definition:

A case was defined as a patient among those undergoing treatment at hemodialysis unit 1, during November and December 2011, who seroconverted to HIV-positive status and whose self-reported behaviors did not include HIV risk factors and whose spouse was seronegative for HIV.

Develop a method for case finding

The investigator conducts a planned search for cases using case definitions to identify new or additional cases of an infection or disease. Looking both backward and forward in time may be necessary to identify new cases as well as additional cases from the past using the time frame in the case definition. Signs and symptoms of the infection or positive laboratory results from the case definition may be used to trigger further investigation to see if a patient matches the case definition. A simple data collection form is usually developed to collect information on possible cases. This form is used to assemble information from medical charts, microbiology reports, pharmacy reports, and logbooks from affected areas. Items to include on the data collection form may vary from outbreak to outbreak but may include:

- Items from the case definition
- Demographic information (age, sex, date and reason for admission, diagnosis, date of surgery or procedures, antibiotics, etc.)
- Clinical data (onset of signs and symptoms, frequency and duration, treatments, medical devices)
- Other relevant data including risk factors depending on the infection

Use the case finding form adapted and approved by your Ministry of Health, if available. The CDC sample Healthcare-Associated Infection (HAI) Outbreak Investigation Abstraction Form is a detailed form that can be adapted for local use and for the type of outbreak: [http://www.cdc.gov/hai/pdfs/outbreaks/Response_Toolkit_Abstraction_Form-508.pdf](http://www.cdc.gov/hai/pdfs/outbreaks/Response_Toolkit_Abstraction_Form-508.pdf).

The example in Box 3-4 demonstrates case finding in an HAI outbreak of *Burkholderia cepacia*. Medical records were reviewed to look for a positive culture with *Burkholderia cepacia*, indicating a possible case. Note that the time frame was from the year before and the current year. Information from the clinical documentation was used to find cases that met the case definition, resulting in the identification of nine previously unrecognized cases.
Box 3-4. Example from the Field: Methods of Case Finding

Staff at a medical intensive care unit (ICU) in Ecuador became concerned in April 2012 when *Burkholderia cepacia* was isolated from tracheal aspirates from three patients followed by a fourth in May. Case finding consisted of reviewing all results of routine cultures from all patients admitted to the medical ICU during 2011 and 2012. Medical records were reviewed for any patient with a positive culture to see if the case definition was met. Nine additional cases were identified using this method. Samples from various solutions used in patient care were taken (water, povidone-iodine solution, mouthwash). The same organism was found in unopened bottles of chlorhexidine 0.12% alcohol-free mouthwash used in the ICU for mouth care. (Zurita et al. 2014)

Confirm the diagnosis for suspected cases

If possible, the clinical diagnosis should be confirmed by laboratory testing. Staff should be given specific instructions to correctly collect samples so that organisms are being captured. If possible, store samples for further and future testing. For example, molecular typing of the isolates may be performed to determine if the organisms causing the infection are related (see Module 1, Chapter 3, Basic Microbiology for Infection Prevention and Control) and for use by the microbiology laboratory in outbreak situations (see Module 11, Chapter 2, Principles of Public Health Emergency Preparedness and Outbreak Management for Health Care Facilities, for more information about case definitions of confirmed and suspected cases).

The example in Box 3-5 shows how potential cases were identified using signs and symptoms of respiratory illness and the diagnosis of Middle Eastern Respiratory Syndrome Coronavirus (MERS-CoV) was confirmed by laboratory testing.

Box 3-5. Example from the Field: Confirming the Diagnosis for Suspected Cases

A cluster of health care-associated cases of MERS-CoV was investigated in a hospital in Saudi Arabia. Suspected cases were those showing signs and symptoms. Upon identification of a suspected case, samples were taken, which, if positive, confirmed the diagnosis of the cases. It was determined that the infection was spread in a ward from one patient to another and to three HCWs. Poor recognition and isolation of potential cases were identified as causes of the transmissions. (Memish et al. 2015)

Prepare an initial line list and an epidemic curve

As cases are identified, they should be entered on a line list where each case is listed with associated characteristics/risk factors. Information from the list can be used to create an epidemic curve showing the distribution of cases over time (WHO 2002). This will be important to help interpret the causes of an outbreak. Box 3-6 shows an example from a neonatal care unit in Japan where a line list was used to describe an outbreak of multidrug-resistant *E. coli*.

A line list should include the clinical characteristics and risk factors of the case (these can be collected using the data collection form and should include sex, age, admission date, symptoms, date of onset of illness, etc.). Each case can be entered on one row with one associated characteristic in each column of the row (see Table 3-3) or each case can occupy a column with one associated characteristic on each row (see Figure 3-2).
Table 3-3. Example of a Template for a Line List

<table>
<thead>
<tr>
<th>Case</th>
<th>ID Number</th>
<th>Age</th>
<th>Sex</th>
<th>Admit Date</th>
<th>Symptoms 1</th>
<th>Symptom 2</th>
<th>Lab Result</th>
<th>Date of Onset</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Box 3-6. Example from the Field: Describing the Outbreak Using a Line List and Epidemic Curve

An outbreak of multidrug-resistant *E. coli* was identified in a neonatal intensive care unit (NICU) in Japan when routine surveillance cultures identified the organism after a year without seeing any cases. Six patients had positive cultures. A line list and epidemic curve were created. The investigation revealed that transmissions were related to breast milk sharing and storage practices in which contaminated breast milk from one mother was shared with multiple babies. See Figure 3-2, which shows the line list and epidemic curve that were developed by outbreak investigators. (Nakamura et al. 2016)

Figure 3-2. Example Line List from an Outbreak Investigation by Nakamura et al. (2016)

Investigating Outbreaks

An epidemic curve plots the cases in an outbreak based on the time of onset of illness. The shape can give clues to the source of the outbreak, which, along with other information gathered in the course of the investigation, can help identify the possible exposure.

Steps for making an epidemic curve

1. Create a horizontal axis (X axis) with increments of continuous time. Start with each increment being 1 day, but depending on the time frame over which the outbreak occurred, these might need to be changed to intervals of days/weeks/months. No time should be left out of the graph as the pattern of cases over time will be important (see Figures 3-3, 3-4, and 3-5).

2. Create a vertical axis (Y axis) with continuous whole numbers starting from 0. This will be the number of cases.

3. On the line list, find the case that occurred first and if no other cases occurred on that day, insert a bar that reaches to the number 1 on the Y axis (or if more than one case, make the bar higher to show the number of cases occurring on that day).

4. For each day, add up the number of cases on the line list and insert a bar on the graph reaching that number.

   **Note:** The bars for consecutive days should be touching each other. Since the time period is continuous, there should not be any gap between the bars.

5. Show confirmed and suspected cases in different colors or shading. If there are confirmed and suspected cases on the same day, distinguish between them by showing them on the same bar but in different colors or shading, with the confirmed cases at the bottom and suspected cases stacked on top.

   (APIC 2014; WHO 2002)

Shapes of the epidemic curve

**Single-point source:** Figure 3-3 shows the epidemic curve created during an investigation of an outbreak of *Salmonella enteritidis* diarrheal illness at a psychiatric hospital in Ireland (Grein et al. 1997). The single source was discovered to be from eggs in a dessert served at lunch on August 26.
Investigating Outbreaks

Figure 3-3. An Epidemic Curve Showing a Single-Point Source from a Health Care-Associated Outbreak of Diarrheal Illness at a Hospital


Ongoing transmission: Figure 3-4 shows the epidemic curve for an outbreak of *Staphylococcus aureus* skin infection among newborns at a hospital in Thailand. The investigators discovered that the infection was being passed by ongoing transmission from one infant to another on the hands of multiple HCWs and on the equipment used in care. The outbreak ended abruptly once hand hygiene and equipment cleaning were improved. (Pawun et al. 2009)

Figure 3-4. An Epidemic Curve Showing Ongoing Transmission from a Health Care-Associated Outbreak of Skin Infection at a Hospital

Investigating Outbreaks

**Intermittent source**: The graph in Figure 3-5 shows the epidemic curve for the intermittent source outbreak of *E. coli* in a NICU in Japan. The contaminated breast milk from one mother was stored and then, over time, taken out of storage and given to different babies. (Nakamura et al. 2016)

*Figure 3-5. An Epidemic Curve Showing Intermittent Source from a Health Care-Associated Outbreak of E. coli in a NICU*


**Observe and review potentially implicated health care practices**

An outbreak can be stopped by identifying and interrupting the chain of transmission. Information from the literature review on the type of pathogen and infection, and review of the cases in the line list, may help identify which health care practices to focus on. Discussing the outbreak and possible causes with staff is also essential. Investigations are more productive if investigators are seen as partnering with the staff rather than attempting to find someone to blame. (APIC 2014)

**Note**: In most outbreaks, actual observations of practices will be the most helpful in identifying the cause (APIC 2014).

Observations should at first be done without a detailed data collection form and should focus on workflow and practices that are different from best practices, recommended IPC guidelines, and hospital policies (APIC 2014). It can be helpful to ask about shortcuts and methods that have been created by staff to work around perceived barriers to make workflow easier (Box 3-7).

**Box 3-7: Useful questions to ask during observations**

- Do you always do this procedure in the way I observed? Are there situations that might require that you do it differently?
- Have you seen other people do it differently?
- What are the challenges with maintaining good techniques?
- What do you think is causing or contributing to the outbreak?
- What procedures or medications might I be missing because they are not in the chart or are done infrequently? (APIC 2014)
General IPC practices such as hand hygiene and Standard Precautions should be observed. The example in Box 3-8 demonstrates the importance of observation and review of health care practices in an outbreak investigation. In this example, the incorrect practice of using a single bag of fluid multiple times to provide flushes for all patients on the unit could never have been identified from the medical records or other documentation.

Box 3-8. Example from the Field: Observing and Reviewing Health Care Practices

The microbiology laboratory in a hospital in Cambodia noticed blood cultures growing *Burkholderia cepacia* from two patients from the same ward within 1 week of each other in 2011. A literature review revealed that this organism is well-known for causing hospital outbreaks and grows in wet environments. During case finding, a review of the medical charts of patients meeting the case definition was performed. This review searched for common medications, procedures, and patient care. These were added to the line list. Health care practices on the ward were also observed. Investigators determined that 1-liter bags of IV solutions were being used as multi-dose vials to flush peripheral IV catheters for all patients in the ward. *B. cepacia* was subsequently cultured from the opened IV bags used to flush peripheral IVs. There was no growth from unopened bags. (De Smet et al. 2013)

Implement initial control measures

Stopping an outbreak is the urgent goal of the investigation. It is acceptable, and the usual practice, to implement a number of mitigation practices—known or thought to prevent the type of infection under investigation—as soon as possible (see Box 3-9). Additional prevention practices may be added during the investigation (APIC 2014). It is always appropriate to educate or reinforce HCWs about IPC precautions and to develop a plan to ensure ongoing compliance with them (APIC 2014). Table 3-4 summarizes measures that may be effective in stopping an outbreak.

Box 3-9. Examples from the Field: Implementing Initial Control Measures

In an outbreak of Legionnaire’s disease in the United States, the first three patient interviews revealed that all three had waited near a decorative fountain during their hospital visit. The interim measure in this investigation was to immediately shut down the decorative fountain while the investigation continued. (Haupt et al. 2012)
### Table 3-4. Sites and Sources of Outbreaks and Measures to Take to Stop Outbreaks

<table>
<thead>
<tr>
<th>Site</th>
<th>Sources and/or Mode</th>
<th>Initial Control Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Urinary tract infection</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Common</td>
<td>Uncommon</td>
</tr>
<tr>
<td></td>
<td>• Urinary tract instrumentation cross-contamination via hands of HCWs</td>
<td>• Inadequately processed instruments</td>
</tr>
<tr>
<td></td>
<td>• Poor hand hygiene</td>
<td>• Contaminated antiseptic solution (e.g., povidone-iodine)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Re-emphasize known aseptic practices relating to insertion and maintenance of urinary catheters, and monitor compliance. (See Module 10, Chapter 2, Preventing Catheter-Associated Urinary Tract Infections.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Institute glove use for any contact with urine.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Separate catheterized patients from each other.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Hand hygiene and put on clean gloves just before contact with urinary meatus.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Wash hands, or use an antiseptic handrub, after removal of gloves.</td>
</tr>
<tr>
<td><strong>Surgical wound</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Common</td>
<td>Uncommon</td>
</tr>
<tr>
<td></td>
<td>• Organisms acquired</td>
<td>• Airborne spread</td>
</tr>
<tr>
<td></td>
<td>• Contaminated products (wound irrigating solutions)</td>
<td>• Preoperative contamination (contaminated antiseptic solution)</td>
</tr>
<tr>
<td></td>
<td>• Poor surgical technique (hemostasis, glove puncture)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Re-emphasize known aseptic practices and surgical technique.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Exclude infected personnel from patient care.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Separate those at risk from those infected.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Hand hygiene and put on sterile or high-level disinfected gloves just before wound contact.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Use sterile fluids for wound care.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Wash hands, or use an antiseptic handrub, after removal of gloves.</td>
</tr>
<tr>
<td>Site</td>
<td>Sources and/or Mode</td>
<td>Initial Control Measures</td>
</tr>
<tr>
<td>----------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td><strong>Common</strong></td>
<td><strong>Uncommon</strong></td>
</tr>
</tbody>
</table>
| Lower respiratory tract | • Colonization of upper airway with secondary aspiration into lung  
• Contamination of nebulized solutions or respiratory therapy equipment surfaces  
• Cross-contamination via hands of HCWs, lack of patient spacing, failure to implement infection control | • Airborne spread                                                                                                                                                                                                       |
|                      |                                                                                                                                                                                                                      | • If respiratory therapy is associated with cases, examine technique used for disinfection and delivery of therapies (e.g., multi-dose vials).  
• Separate those at risk from those infected.  
• Hand hygiene and put on clean gloves just before contact with mucous membranes and suctioning of patients.  
• Wash hands, or use an antiseptic handrub, after removal of gloves. |
| Blood                | • Intravascular, especially central venous catheters  
• Contamination of insertion site                                                                                                                                                                                      | • Hand hygiene and put on sterile gloves before inserting catheter.  
• Wear gloves for wound contact.  
• Wash hands, or use an antiseptic handrub, before contact with the intravascular catheter.                                                                 |  

*Adapted from:* Lynch et al. 1997.

Consider whether to perform environmental sampling

If environmental sampling is an option, very careful consideration should be given before deciding upon this course of action due to cost, lack of standards for interpretation, and the high possibility of inconclusive results (APIC 2012; APIC 2014).

**Note:** Environmental sampling should be pursued only if there is strong epidemiological evidence indicating that a possible source or reservoir of organisms exists.

It is important to note that if negative results occur it will not be known if that site in the environment can be ruled out as a potential source of the outbreak or if the sampling failed for some reason. There are many reasons why sampling the environment might not reveal a source pathogen, even if it is present. Perhaps the collection or culture technique was not adequate. Perhaps the pathogen was already removed by cleaning or only present transiently. Perhaps the sample was taken from the wrong place. See the Common Mistakes in Outbreak Investigations section below. Often environmental sampling may not be possible due to lack of lab capacity or supplies and it is not essential. On the other hand, if environmental sampling is indicated and possible, a positive result matching the pathogen causing the outbreak can be very satisfying (see Box 3-10 for an example from the field).
Investigating Outbreaks

Recommendations that can improve environmental sampling and the yield of environmental cultures include:

- Perform these cultures after making the line list and doing observations so that they can focus on items that seem the most likely to be implicated. Environmental cultures should never be the first step in an outbreak investigation.

- Before obtaining any environmental cultures, talk with microbiology laboratory personnel to determine whether they are able to process the cultures that will be obtained and discuss the optimal methods of obtaining them.

- Culture only items that are possible vectors of transmission.

- Culture the items that make the most sense as the likely reservoir for the organism. For example, outbreaks of *Pseudomonas* should focus on liquid items, whereas outbreaks of *Acinetobacter* should focus on surfaces.

(APIC 2014)

**Box 3-10. Examples from the Field: Environmental Sampling**

The environment and processed endoscopes were sampled to help identify the source of an outbreak of multidrug-resistant *E. coli* in a hospital in the United States. No reservoir was identified in the environment. However, investigators found that two of eight of the complex endoscopes were found to be harboring the organism even after proper cleaning and disinfection. (Wendorf et al. 2015)

**Additional steps**

Outbreak investigations should be approached as a cycle with continuous re-evaluating and refining until the outbreak ends. As you continue to follow the outbreak, these steps will also be necessary:

- Refine the case definition.

- Continue case finding and surveillance.

- Review control measures regularly.

- Communicate findings during and after the outbreak investigation.

- Consider if further study or investigation is needed. See Module 9, Chapter 1, Basic Epidemiology and Statistics for Infection Prevention and Control, in this module for details about designing a study to investigate an outbreak.

(APIC 2014)

**Common Mistakes in Outbreak Investigations**

- An assumption that an outbreak exists when it really does not. An apparent increase in cases over a short period is often only normal variation; therefore, where possible, confirm the diagnosis, search for additional cases, and determine whether the increase is real before concluding that an outbreak is occurring.

- Environmental sampling when not indicated. Isolation of an organism from the environment rarely explains an outbreak (see the Consider Whether to Perform Environmental Sampling section above).
● Mistaken interpretation of environmental samples:

  • The presence of organisms from multiple sites or from HCWs usually suggests that these sites became colonized from another source and were not the cause of the outbreak.

  • Negative cultures do not justify concluding that the site (e.g., HCW or inanimate object) was not responsible for the outbreak. There could be many reasons the cultures were negative: incorrect specimen collection and handling; poor culture technique, including performing the test incorrectly or using the wrong reagents; and failure to collect the right specimen.

● Prevention measures not implemented immediately. As soon as an outbreak is suspected, patient care practices that could be responsible should be evaluated and any problems identified and corrected, without waiting for results from an investigation. (Table 3-4 outlines common sources for HAIs at various sites and some recommended risk-reduction practices; the Implement Initial Control Measures section gives more information.)

● Other similar situations and related practices not evaluated. When a problem with reprocessing instruments or specific patient care practices is identified, often the same faults exist elsewhere in the facility; all similar situations and related practices should be evaluated and corrected as soon as possible.

**Communicating Information about Outbreaks**

If an outbreak is identified, it is important to communicate early and clearly. See Module 11, Chapter 2, Principles of Public Health Emergency Preparedness and Outbreak Management for Health Care Facilities.

It is also important to notify the public health authorities and other facilities that may have had contact with the patients or may use some of the same practices or commercial products that were responsible for the outbreak. For example, an outbreak caused by contaminated IV fluids or an HAI outbreak caused by *Clostridium difficile* should be communicated as there may be cases at other facilities.

Hospitalized patients, HCWs, and visitors are all linked to their community and there can be considerable interaction between health care facilities. Patients can try alternative medicine, transition to care in a clinic, use an ambulance, visit an emergency room, have an inpatient stay, and be discharged to a nursing home or receive care at home—all in the same episode of illness. As a result, many HCWs, patients, and visitors may be affected by an outbreak. For example, HAI outbreaks of measles and hepatitis B have resulted in cases in the community because information regarding an outbreak or exposure in a hospital was not shared.

Assistance is often available from health authorities and organizations such as WHO and CDC if the outbreak is significant. In 2000, WHO developed the Global Outbreak Alert and Response Network (http://www.who.int/csr/outbreaknetwork/en/). This is a network of existing institutions that pool resources to rapidly identify, confirm, and respond to outbreaks of international importance.
Summary

Despite best efforts to prevent them, outbreaks of HAIs can occur in any health care setting and pose a threat to patients and staff. To halt an HAI outbreak, it is important to identify and interrupt the process or practice responsible for transmission as quickly as possible. Modification of one or more of the sources of an outbreak will end the outbreak and help to prevent similar outbreaks in the future. Actual observations of practices will be the most helpful in identifying the cause. Outbreak investigations should be conducted in a standardized manner. In the investigation of an outbreak, key steps must be implemented at the same time and with continuous re-evaluating and refining until the outbreak is ended. Clearly, communicating with the community and reporting the outbreak to the relevant health authority are also important in case the problem is more widespread.
References


