SECTION 3: INTERPRETATION OF SURVEILLANCE RESULTS

3.1. Reporting of Infection Rates

When considering infection rates, questions that may be asked include:

- How does a hospital's infection rate compare with the aggregated rate of others?
- How have these rates changed over time?

Collection of valid surveillance data and calculation of infection rates may facilitate investigation of abnormally high rates and implementation of interventions. However, comparisons of infection rates must be made with caution and an understanding of the relevant assumptions and limitations.

3.2. Comparison of Rates – Basic Statistical Concepts

3.2.1. The Mean

The mean is usually described as the arithmetic average of a set of numbers. It is the sum of the numbers divided by the total sample size of the group of numbers.

It can be useful to compare your hospital's ratios and rates with the VICNISS mean ratios and rates, which are calculated from all of the hospital data combined. However, the problem with using a mean is that as an average, they can be "distorted" by one or two outliers, i.e. numbers that are very high or very low compared with the rest of the values.

For example, consider the following set of ten numbers: 100,101,103,103,105,110,112,114,115 and 766. This set of values has a mean of 162.6. This mean is quite high when you consider that most of the numbers (9/10) are 115 or less. To overcome this problem, sometimes better measures to use are the median or other percentiles.

3.2.2. The Median and Other Percentiles

Percentiles provide information about the distribution of a group of numbers. For example, consider the set of numbers 1,1,2,2,2,4,4,4,5,5,7,7,8,9,9,12,13,14,14 and 19. It is fairly obvious that this set of 20 numbers, all between 0 and 20, are not evenly distributed. Ten of the numbers are less than 6. Most of the numbers are less than 10. Only five numbers are between 10 and 20.

For this particular set of numbers, half of the numbers are less than 6 and half of the numbers are greater than 6. Thus, 6 is known as the 50^{th} percentile for these numbers. *The 50^{th} percentile is also known as the median*. Other percentiles, however, can also be used. The 25^{th} percentile of this set of numbers is 3, as a quarter of the numbers are less than 3 and three quarters of them are greater than 3. Commonly used percentiles include 10, 25, 50, 75 and 90. Knowing the percentiles for a set of numbers provides a great deal more information about the distribution of the numbers than just the mean.

3.2.3. Risk Stratification

When comparing infection rates it is vital that any comparisons made are valid and useful. One of the major considerations is that rates should be calculated based on groups of patients with a similar infection risk.

Stratification is a technique to control for differences in distribution of risk by subdividing a larger population into groups with similar attributes. For surveillance of some types of heathcare-associated infections, a method of achieving this is through use of a risk index. Individuals are given a score based on their estimated risk of infection relative to other individuals. Comparisons are then made between infection rates based on groups of individuals in the same risk category, who therefore have been deemed to have a similar level of risk.

An example of risk stratification is SSI surveillance patients who are stratified according to VICNISS Procedure Groups (combinations of clinically similar operative procedures). Within the group, patients are further stratified using the basic NHSN risk index (see below). Using groups of operative procedures (based on NHSN) and the NHSN risk index allows for comparisons of rates with international data collected using the same methodology.

Basic NHSN Risk Index

The basic NHSN risk index is patterned after the Surgical Wound Index (SWI) developed during the SENIC project and is used in the NHSN and VICNISS programs.[1,2] This SSI Risk Index is calculated by allocating one point to the patient for each of the following:

1. ASA classification of ≥3.

2. Contaminated or Dirty/Infected wound classification.

3. Operation lasting more than t hours where t is the approximate 75th percentile of the duration of surgery for that particular operative procedure. That is, 75% of the operations for that procedure were shorter than t hours and 25% were longer than t hours. (VICNISS will use US duration of surgery data until there is sufficient local data, and this will allow comparison with US and international infection rates).

This concept is illustrated in Table 3.1. The resulting risk index is a number between 0 and 3 allocated to each patient.

Table 3.1 Determining the Risk Index Category

	ASA Score	Wound Class	Operation > t Hours	Final Risk Index
Patient 1	4 (1 point)	Dirty (1 point)	Yes (1 point)	1+1+1=3
Patient 2	2 (0 points)	Clean (0 points)	No (0 points)	0+0+0= 0
Patient 3	2 (0 points)	Clean-contaminated (0 points)	Yes (1 point)	0+0+1=1

Modified NHSN Risk Index

For **cholecystectomy** and **colon surgery**, the use of a laparoscope has influenced the risk of developing SSI. Use of a laparoscope to perform the surgery has been incorporated into the modified index by subtracting 1 from the patient's risk index if a laparoscope was used for their surgery. The result is a 5 level index, M (for minus 1), 0, 1, 2 or 3 for these operations.

For **appendicectomy** and **gastric surgery**, the laparoscope only influenced the risk where the patient's basic risk index was 0. Therefore, for these operations the index includes 0-No where a laparoscope **was not** used on a patient with basic risk index 0 and 0-Yes where a laparoscope **was** used on a patient with basic risk index 0. All other patients are classified as risk index 1, 2 or 3 and use of the laparoscope is not taken into account.

In addition, sometimes patients in two adjacent risk categories are combined for comparison and reporting purposes for a particular procedure if it has been demonstrated that the risk is not statistically different. For example, patients undergoing cardiac surgery with risk index 2 or 3 have in the past been found to have risks that are not significantly different, and these rates are often reported together in one category designated ‘2,3’.

SSI Rates Stratified by Risk Index

Rates are calculated using the following formula: *Note that rates are expressed per 100 procedures*.

$$Rate = \frac{\text{number of SSI in patients in risk index category } r \text{ who had a particular VICNISS operative procedure}}{\text{number of patients in risk category } r \text{ who had that procedure}} \times 100$$

Table 3.2 Sample Calculations of SSI Rates for Appendicectomies

Risk Category	Number of SSI	Number of procedures	SSI rate (per 100 procedures)
0-No	1	50	1/50 X 100 = **2.0**
0-Yes	0	110	0/110 X 100 = **0.0**
1	2	94	2/94 X 100 = **2.1**
2	2	76	2/76 X 100 = **2.6**
3	2	42	2/42 X 100 = **4.8**

3.2.4. Comparison of Rates with Aggregated Rates

Once risk stratified infection rates are calculated, an individual hospital’s rates may be compared with the VICNISS aggregate rates. Any two infection rates may also be compared using a statistical test. For example, a particular Surgeon’s SSI rate may be compared with the VICNISS or hospital aggregate.

Most statistical tests for comparing rates or proportions do so by assuming that the rates are equal, and test the difference between the rates to see how likely it is that the difference is due to chance, or whether there may be a “real” or statistically significant difference. Output from these tests normally includes a p value and confidence intervals (see below).

3.2.5. The p value

The p value represents the probability that the difference between two rates (or other sets of values) has arisen solely by chance.

Chance can play a part because an infection rate is calculated based on a particular set of data, for example all ICU infections occurring at Hospital A between the beginning of January and the end of March 2011. This set of data is a subset, or sample, of all of the ICU infection data theoretically possible to collect. Thus, the rate calculated from this sample data is an estimate of the “true” infection rate. If, for example, data is collected between June and August in the same year and the infection rate is calculated again, the rates may be expected to be similar but not identical. In the same way a hospital’s infection rate may be expected to be similar but not identical to the VICNISS aggregate infection (mean) rate.

The p value examines the probability that a difference between two rates has arisen by chance. If this probability is high, it is likely that any difference between the rates is due to chance.

If however, this probability is low (**usually < 5% or 0.05 is used as a cut off point**, but this is arbitrary) then it is usually concluded that the difference in rates is unlikely to be due to chance alone, and represents a “real” or significant difference. The difference between the two rates is considered to be **statistically significant**. It is important to recognise that statistical significance does not necessarily imply clinical or practical significance. For example, a rate that is significantly higher than the aggregate rate does not necessarily imply that there is an infection control problem that needs to be addressed. The p value should only ever be used as a guide.

A reason for caution when using p values is that the p value is not always straightforward to interpret. Two factors affect the p value: the magnitude of the difference between the two rates, and the sample size. This means that for **large** sample sizes, even a **small** difference between two rates may be statistically significant, whereas for **small** sample sizes a **large** difference between two rates may not be statistically significant.

To overcome some of this difficulty in interpreting p values, confidence intervals may also be calculated to help evaluate the role of chance in the results, that is, the observed difference between the two rates.

3.2.6. Confidence Intervals (CI)

A confidence interval for an estimate (for example an infection rate estimate) represents the range within which the true value could be expected to lie with a certain degree of assurance. For example, 95% confidence intervals for an infection rate represent the range of values within which the true rate could be expected to lie 95% of the time.

The confidence interval provides additional information to the p value in that the width of the confidence interval indicates the amount of variability in the estimate and thus reflects the effect of sample size. A small sample size will result in an estimate with wide confidence intervals, indicating it is ‘less certain’ that the estimate is close to the true value of the rate.

Table 3.3 shows sample results from comparing SSI rates for an individual surgeon with VICNISS aggregate rates.

Table 3.3 Comparing SSI Rates for Surgeon A by Procedure with VICNISS Rates

Procedure	Risk Index Category	No. of SSI	No. of Operations	SSI Rate (Surgeon A)*	VICNISS Rate*	p-value	95% CIs for Surgeon A's Rate
Cardiac Surgery	0	0	2	0.0			0.00 – 84.19
	1	3	80	3.8	1.7	0.15	0.78 – 10.57
	2,3	1	2	5.0	2.8		1.26 – 98.74
CBGB	0	1	1	10.0	0.7	0.08	0.25 – 44.50
	1	10	230	4.3	3.5	0.30	2.10 – 7.85
	2		120	4.2	5.8	0.29	1.37 – 9.46
	3	5	60	8.3	17.5	0.11	2.76 – 18.39
Total		25	522	4.8	---	---	3.12 – 6.99

* Rates are per 100 procedures

Note that the p value reveals no significant differences between Surgeon A's rates and the VICNISS rate, however half of his/her rates are higher than the VICNISS rate. It is also apparent that his/her surgical volume is relatively low in all but risk category 1 for the CBGB group. This is reflected in the wide confidence intervals for the corresponding rate estimate. For example, for cardiac surgery, for risk index 2,3 the sample size is only 2 operations and this is reflected in the wide confidence intervals which are 1.26 – 98.74. Note also that the confidence intervals for most of Surgeon A's rates encompass the VICNISS rate, meaning that Surgeon A's rate could be closer to the VICNISS rate given a larger sample size.

The procedures for comparing a hospital's rates with the VICNISS aggregate rates are identical to those described here.

3.2.7. Standardised Infection Ratio (SIR)

A table of comparisons such as that described above provides the most specific method of comparing Surgeon A's rates against the VICNISS aggregates. However another measure known as the Standardised Infection Ratio (SIR), which is a risk adjusted measurement of Surgeon A's **overall** experience may also be helpful.

Surgeon A's patients had 25 surgical site infections from 522 operations for an overall (crude) rate of 4.8%. Given the types of procedures performed and the distribution of Surgeon A's patients by risk index, the number of infections which could have been expected to occur among Surgeon A's patients can be calculated using the VICNISS rates.

For example, for CBGB risk index 1, Surgeon A performed 230 operations. If his/her rate was the same as the VICNISS rate (3.5 per 100 operations) we would have expected Surgeon A to have 8.05 infections in this group, calculated as follows:

$$230 \times 3.5\% = 8.05$$

This calculation is performed for each risk index category and each surgery type (see Table 3.4).

Table 3.4 Calculation of Expected Numbers of SSIs for Each Category and Standardised Infection Ratios

Procedure	Risk Index Category	Observed No. of SSI	*No. of Operations*	SSI Rate (Surgeon A)	*VICNISS Rate*	Expected number of SSI	Standardised Infection Ratio (SIR)
Cardiac	0	0	2	0.0			**---**
Cardiac	1	3	80	3.8	1.7		**2.20**
Cardiac	2,3	1	2	5.0	2.8	1.10	**0.90**
CBGB	0	1	1	10.0	0.7	0.07	**14.30**
CBGB	1	10	230	4.3	3.5	8.05	**1.20**
CBGB	2		120	4.2	5.8	6.96	**0.71**
CBGB	3	5	60	8.3	17.5	10.50	**0.48**
Total		25	522	4.8	---	28.05	**0.89**

Once the expected numbers have been calculated for **ALL** risk index categories, the expected and observed numbers in each category are totalled and the SIR is calculated as follows:

$$SIR = \frac{\text{Observed number of SSIs}}{\text{Expected number of SSIs}} \quad \frac{25}{28.05} = 0.89 \text{ for Surgeon A}$$

Although a SIR has been calculated for each risk index category, the SIR for all of Surgeon A’s procedures gives a single, easy to interpret measure of his overall experience.

If the SIR is less than 1, it means that Surgeon A had, overall, less infections than were expected according to the aggregate rates. If, however, Surgeon A’s SIR exceeds 1, then more infections occurred than were expected. Since the SIR incorporates the type of operations performed and the distribution of patients by risk index it can be used for comparison. Care should be exercised when making comparisons, however, as the risk index is limited and does not control for all possible factors which may contribute to an individual surgeon’s or hospital’s rates.

3.2.8. Risk Stratification and Standardised Infection Ratio for Caesarean Section

Basic risk stratification as used by NHSN and VICNISS consists of a point system. Each patient is assigned a level of risk according to their ASA score, wound class and duration of operation. However, for several procedures where this risk stratification has been shown to be less effective in predicting infection risk, a different approach is taken.

This approach involves applying statistical techniques to the results of a large study in order to identify which risk factors are predictive of infection risk and the relative contribution each risk factor makes to the final risk. These analyses have been carried out by NHSN and the results are applied to the Victorian data.

For incisional SSI following caesarean sections the risk factors which were shown to be significant were the patient’s body mass index (BMI), estimated blood loss, age, ASA score and duration of labour.

The result of the analysis is a model that allows, for each patient, calculation of a **probability** of that patient acquiring a healthcare associated infection. The probabilities are then used to calculate an expected number of infections for the particular group of patients under surveillance and this is compared with the actual number of infections that occurred.

The most important difference with this sort of risk stratification is that it does not result in a rate for infection that can be compared with an aggregate rate, but in a **standardised infection ratio (SIR)**. The SIR is calculated as follows:

$$SIR = \frac{\textit{Observed number of infections}}{\textit{Expected number of infections}}$$

A SIR of >1 means that more infections were detected than would have been expected, whereas a SIR of <1 means that less infections were detected than were expected.

Table 3.5 Calculation of Standardised Infection Ratios for Caesarean Sections

Patient no	BMI	Estimated blood loss (ml)	Age	ASA	Duration of labour (hours)	Incisional SSI	Probability of Incisional SSI (calculated using model)
1	25	489	29	0	12	No	**0.095**
2	27	678	33	0	10	No	**0.073**
3	32	800	28	1	8	**Yes**	**0.129**
4	24	567	34	0	14	No	**0.068**
5	35	450	22	1	9	No	**0.14**
6	29	200	25	0	10	No	**0.07**

It can be seen in Table 3.5 that the observed number of infections is 1. The expected number of infections is calculated by adding the probabilities for each patient = 0.575.

The SIR = $^{1}/_{0.575}$ = 1.74

3.2.9. Risk Stratification and Calculation of Rates for ICU/NNL (CLABSI, PLABSI and VAP)

Risk Stratification

VICNISS reports ICU data by Category 1A hospitals and 'Other':

ICU – Category 1A

- St Vincent's Hospital, St Vincent's Health
- The Royal Melbourne Hospital, Melbourne Health
- Monash Medical Centre, Southern Health
- The Alfred, Bayside Health
- Austin Hospital, Austin Health
- Geelong Hospital, Barwon Health

- Epworth Richmond
- Melbourne Private Hospital

ICU – Other

- Ballarat Base Hospital, Ballarat Health Services
- Bendigo Hospital, Bendigo Health Care Group
- Box Hill Hospital, Eastern Health
- Maroondah Hospital, Eastern Health
- Dandenong Hospital, Southern Health
- Shepparton Campus, Goulburn Valley Health
- Latrobe Regional Hospital
- Frankston Hospital, Peninsula Health
- Warrnambool Hospital, South West Healthcare
- Northern Hospital, Northern Health
- Wangaratta Hospital, Northeast Health
- Western Hospital, Western Health

- St John of God Hospital Geelong
- St John of God Hospital Bendigo
- Epworth Freemasons
- Epworth Eastern

NNL

- Mercy Hospital for Women
- Royal Women's Hospital
- Royal Children's Hospital
- Monash Medical Centre, Southern Health

Calculation of ICU Rates

From data collected in the ICU (and NNL) surveillance module three basic types of calculations can be carried out.

A. Device utilisation ratios are a measure of device use per patient days in the ICU. The use of certain devices plays an important role in determining the risk of infection. Device utilisation ratios for individual hospitals can be calculated and compared with the aggregate (mean) ratio and the distribution of all VICNISS hospital ratios. The following formulas are used to calculate device utilisation ratios:

$$\textit{Central line utilisation ratio} = \frac{\textit{number of central line days}}{\textit{number of patient days}}$$

$$\textit{Peripheral line only utilisation ratio} = \frac{\textit{number of peripheral line only days}}{\textit{number of patient days}}$$

$$\textit{Ventilator utilisation ratio} = \frac{\textit{number of ventilator days}}{\textit{number of patient days}}$$

$$\textit{Overall device utilisation ratio} = \frac{\textit{number of central line days + number of ventilator days}}{\textit{number of patient days}}$$

Table 3.6 is an example of the comparison of a particular hospital's device utilisation ratios with the VICNISS aggregate ratios. Hospital A's device utilisation ratios have been calculated and can be directly compared with the **mean** and **percentiles** of the VICNISS aggregate device utilisation ratios.

Table 3.6 Example Comparing Hospital A's Device Utilisation Ratios with the Mean of the Aggregate VICNISS Data

	Hospital A Device Utilisation Ratio	VICNISS Aggregate Device Utilisation (Mean) Ratio
Central Line Utilisation	0.78	0.80
Ventilator Utilisation	0.60	0.47

In the example above, Hospital A's central line utilisation ratio is slightly below the mean whereas the ventilator utilisation is higher than the mean for the VICNISS aggregate device utilisation ratios.

B. Device associated infection rates are calculated using the number of device days (or patient days) as the denominator in order to adjust for the risk associated with exposure to the device and allow for more valid comparisons. Rates are normally reported as infections per 1000 device (eg central line, ventilator) days. Separate infection rates are calculated for each type of device related infection. These may then be compared with the VICNISS aggregate rates.

In the US differences are seen in infection rates in major teaching hospital mixed medical/surgical ICUs as compared to other hospitals. When making comparisons between individual hospitals and the VICNISS aggregate rates this issue must be kept in mind for the purposes of interpretation of any observed differences in rates.

The following formulas are used for calculation of the overall device associated infection rate, the central line associated bloodstream infection (CLABSI) rate, the peripheral line associated infection rate (PLABSI) and ventilator associated pneumonia (VAP) infection rate.

$$\textit{Overall device infection rate} = \frac{\textit{number of infections in patients with devices}}{\textit{number of patient days}} \times 1000$$

$$\text{Central line associated bloodstream infection (CLABSI) rate} = \frac{\text{number of bloodstream infections (BSI) in patients with central lines}}{\text{number of central line days}} \times 1000$$

$$\text{Peripheral line only associated bloodstream infection (PLABSI) rate for infants} \leq 1000\text{gm} = \frac{\text{number of peripheral line only bloodstream infections (BSI) in infants} \leq 1000\text{gm}}{\text{number of peripheral line only days in infants} \leq 1000\text{gm}} \times 1000$$

$$\text{Ventilator associated PNEU rate} = \frac{\text{number of PNEU in patients who were on a ventilator}}{\text{number of ventilator days}} \times 1000$$

Table 3.7 Example Comparing Hospital A's Device Associated Infection Rates with the Distribution of VICNISS Rates

	Hospital A's Device Associated Infection Rate*	VICNISS Aggregate (Mean) Infection Rate*
Central line associated bloodstream infection	7.0	6.0
Ventilator associated pneumonia	0.9	5.3

***** Rates are calculated per 1000 device days

In the example shown in Table 3.7, Hospital A's rate for central line associated BSI is 7.0 per 1000 device days. This is higher than the VICNISS aggregate mean infection rate of 6.0.

A further test can be carried out to test whether the difference between two rates is statistically significant. This involves using a standard statistical test to evaluate the difference between the two rates. The results of this test include a p value and confidence intervals. These two elements help to assess whether the difference between the rates is statistically significant.

Table 3.8 Comparing Hospital A's Device-associated Infection Rates with VICNISS Aggregate Rates using a Standard Statistical Test

Infection type	Hospital A's device associated infection rate*	VICNISS aggregate device associated infection rate*	p value derived from comparison of rates	95% CI s for Hospital A's rate
Ventilator associated pneumonia	19.4	11.2	0.03	12.8 – 23.6
Central line associated bloodstream infection	6.8	7.4	0.64	4.8 – 8.1

**Rates are calculated per 1000 device-days.*

In the above example, Hospital A appears to have a high ventilator associated pneumonia rate. Is this rate significantly higher than the VICNISS aggregate rate? To address this question a p value for the comparison of the rates and confidence intervals for Hospital A's rate is calculated using a statistical test.

Comparison of the rates for VAP results in a p value of 0.03. This means that the probability that the difference in the rates is due to chance is 0.03. As this is less than 0.05, we conclude that the difference in the rates is a statistically significant result. Examining the confidence intervals for the estimate, the lower 95% confidence interval is 12.8 and the upper one is 23.6. This means that

Hospital A's infection rate is likely to lie within this range in 95 out of 100 samples. These confidence intervals are quite wide, and this may indicate that the sample size (not shown here) from which this rate was calculated was small. Some caution would therefore be indicated in concluding that Hospital A's rate was higher in a meaningful sense, since the true rate for Hospital A might be closer to 12.8 which is not much higher than the VICNISS aggregate rate.

Comparison of the central line associated bloodstream infection rates results in a p value of 0.64. It could be concluded that the difference between Hospital A's rate for BSI and the aggregate rate may have been due to chance and is not statistically significant. Note, however, that the confidence intervals in this case are relatively narrow, and this could be because of a large sample size giving a reliable estimate of Hospital A's rate.

In this type of comparison between two rates two important points should be taken into account:

- Does the p value indicate that the difference is statistically significant?
- Are the confidence intervals narrow, suggesting that the sample size was sufficient to give a good estimate of the rate?

If both of these conditions are satisfied, we can be reasonably sure that there is a difference between the rates, which is not just a result of chance variation.

C. Average length of stay is sometimes used as a proxy for infection risk and can be calculated from data collected for the denominator. This is not currently reported by VICNISS.

The formula for calculating average length of stay (ALOS) for a particular month is:

$$\text{ALOS} = \frac{d}{c + \frac{a}{2} - \frac{b}{2}}$$

Where:

a = number of patients in ICU on the first day of the month.

b = number of patients in ICU on the first day of the next month.

c = number of patients admitted to the ICU during this month (calculated from the new arrivals field which is completed daily).

d = number of days spent by all patients in the ICU during this month (calculated from the total number of patients column which is completed daily).

The average length of stay for each month in which ICU surveillance is undertaken can be calculated and compared with the infection rates for the same time period.

References

1. Haley RW, Quade D, Freeman HE, Bennett JV. The SENIC Project. Study on the efficacy of nosocomial infection control (SENIC Project). Summary of study design. Am J Epidemiol. 1980 May;111(5):472-85.

2. Culver DH, Horan TC, Gaynes RP, Martone WJ, Jarvis WR, Emori TG, Banerjee SN, Edwards JR, Tolson JS, Henderson TS, et al. Surgical wound infection rates by wound class, operative procedure, and patient risk index. National Nosocomial Infections Surveillance System. Am J Med. 1991 Sep 16;91(3B):152S-157S.