Antimicrobial Susceptibility Patterns of Pathogens Isolated from Surgical Site Infections at Public Health Facilities in Belize

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Abstract

Surgical site infections are amongst the leading cause of morbidity, mortality and cost due to increase in hospital stay. A study was conducted to understand antimicrobial susceptibility patterns of major pathogens isolated from surgical site infections in Belize. A laboratory experiment was done to establish the antibiogram in pathogens. A retrospective study was conducted utilizing existing data captured through the Belize Health Information System, Ministry of Health. Raw data from 2009-2017, was compiled and arranged in an orderly manner and a detailed statistical analysis was carry out using SPSS and Microsoft-Excel. Descriptive analysis was conducted to extrapolate sensitivity patterns of isolates. From 630 samples only 50% (315) had pathogen growth. The number of cases reported was highest in 2013. A single pathogen was isolated from 93.3% of samples while multiple pathogens were isolated from 6.7% of samples. Out of the 341 cases where pathogens were isolated, the most common was *Staphylococcus aureus* (31.1%), followed by *Escherichia coli* (17.6%), *Klebsiella spp* (13.5%), *Pseudomonas aeruginosa* (9.7%) and *Enterobacter spp*. (6.45%). Aerobic Gram negative bacteria accounted for 58.1%, while aerobic Gram positive bacteria accounted for 38.4%. Cesarean procedures accounted for the highest number of infections with 28.3% while the age group most affected was between 20 - 29 years of age. *Staphylococcus aureus* was more resistant to Erythromycin (62.1%) and Imipenem (60%), and less resistant to Vancomycin (5.4%) and Trimethoprim/Sulphamethoxzole (8%). *Escherichia coli* was more resistant to Erythromycin (100%) and Tetracycline (68.2%) and less resistant to Imipenem (0%) and Amikacin (5.4%). *Klebsiella spp* was more resistant to Tetracycline (66.7%) and Trimethroprim/Sulphamethoxzole (62.5%) and less resistant to Imipenem (0%) and Amikacin (4.7%). The antimicrobial resistant patterns of many pathogens showed that more than 20% of all isolates were resistant to most antibiotics in all the years of the study with some isolates were seen multidrug resistant. More than 50% of all isolates during the study period showed resistance to erythromycin and more isolates were susceptible to Gentamycin.

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I declare that this is my own work, and that it does not contain material that has already been use to any substantial extent for a comparable purpose.

Name of Student: __________________________ Signature: _________________________

Date: _________________________________

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Introduction

Infections after a surgical procedure are one of the leading causes of morbidity and mortality globally. Health care-associated infections (HAIs) are infections acquired by patients when receiving medical treatment at a healthcare institution. HAIs is a major safety concern for both health care providers and the patient, as they can present a major risk to human health when considering morbidity, mortality, increased length of hospital stay and added cost to both patient and health care system. Common HAIs include urine, blood, chest, and wound infections (Plowman *et al.* 2001). One of the most studied type of HAIs are those related to surgical procedures. These types of infections are referred to as surgical site infections (SSIs). SSIs are potential complications that can occur after surgery is done in any part of the body. As defined by the Center of Disease Control (CDC), surgical site infections can sometimes be superficial infections that happen only in the superficial layers of the skin, or in some instances involve more invasive procedures that can involve tissues under the skin, organs, or implanted material. Even though surgical site infections fall under one of the most preventable HAIs, they still represent a significant burden in terms of morbidity and mortality as well as additional costs to health systems due to increase length of hospitalization (CDC 2010). According to recent reports from the World Health Organization (WHO), SSIs threaten millions of patients each year and is also a major contributor to the spread of antibiotic resistance (WHO - Surgical Site Infections 2016).

Antibiotics are medicines used to prevent and treat bacterial infections. Resistance to antibiotics occur when a bacteria changes its response to the use of this medicines making their use ineffective. In the case of resistance, the bacteria becomes resistant to the antibiotic and not the other way around, were individuals were thought to become resistant to antibiotics. In the event antibiotic resistant bacteria infect humans the infections they cause are harder to treat, when compared to those caused by non-resistant bacteria (Read and Woods 2014). The use of antibiotics has long been transformed the field of medicine and saved millions of people around the globe from many infectious diseases. The emergence of antibiotic resistant bacteria is escalating at alarming rates worldwide endangering the life of many. Several factors are said to contribute to the antibiotic crisis, primarily with the overuse of antibiotics, it is believed that the overuse of antibiotics is what has driven bacterial evolution towards resistance. Studies have established the existence of a direct relationship between antibiotic use and the occurrence and spread of bacterial strains that are resistant (Ventola 2015). Furthermore, it has been shown that incorrectly prescribed antibiotics can also contribute to the growing number of resistant bacteria; in majority of cases prescribed antibiotic treatment, specific agent, or duration of antibiotic treatment is incorrect in 30% to 50% of events (Luyt *et al.* 2014), contributing immensely to bacterial resistance. In some countries the problem is lack of regulations to controls the easy access to antibiotics, making antibiotics available over the counter without the need of a prescription. While in other countries where prescriptions are necessary the accessibility of purchasing antibiotics online makes it easier to access in places were regulations are in place (Michael *et al.* 2014).

Antibiotic resistance was initially believed to be a health facility related problem, however today the antibiotic resistance phenomena has spread to the point where everyone is at risk, as more and more pathogens are becoming resistant. One contributing factor to the change in antimicrobial susceptibility is attributed to the use of antibiotics in agriculture and life stock production. Although the implications of the use of antibiotic in life stock production are not yet clear as to how it relates to the emergence and spread of antibiotic resistance, it is believed that the routine use of antibiotics in life stock production is a major contributor to the clinical problem of resistant pathogens in human medicine (Chang *et al.* 2015). In places were antibiotics can be purchased without a prescription either for human or animal use make the emergence and spread of resistance worse as antibiotics tend to be over prescribed and over used by population.

Antimicrobial resistance is considered to be one of the most pressing public health issues the world faces today. It is occurring worldwide, threatening the effective prevention and treatment of an increasing number of infections caused by multiple pathogens. Governments around the world are focusing attention and efforts to the problem as it undermining many other advances in the field of medicine and health. In 2014 the World Health Organization stated that a post-antibiotic era is a possibility for the 21st century as the antimicrobial crisis is becoming dire (WHO 2014c).

Estimates of the economic impacts of antimicrobial resistance have been carried out, and the findings are worrisome. For instance, the yearly cost to the US health system alone has been estimated at US $21 to $34 billion dollars, followed by more than 8 million additional days in hospital. Moreover considering that antimicrobial resistance affects far beyond the health sector, it is anticipated that it will cause a fall in real gross domestic product of 0.4% to 1.6%, which means several billions of dollars globally (WHO 2014a).

Pathogens are adapting new resistance mechanisms and spreading globally, causing a major threat to the ability of treating common infections. The list of infections that are becoming harder to treat keep getting longer. If actions are not taken, the outcomes of infections might be disastrous and reach the point were common infections and minor injuries can once again cause death amongst the population.

Review of Literature

In order to determine the sensitivity or susceptibility of microbes to antibiotics, an antibiogram must be carried out. An antibiogram provides an overall sensitivity profile results of specific bacterial isolates to a battery of antimicrobial drugs. Antibiograms are often used by clinicians to be able to select the correct antibiotic for causative bacteria. They serve as a guide for clinicians and pharmacist in selecting the best empiric antimicrobial therapy, in the event of pending culture and susceptibility results. This susceptibility results can be used to monitor resistance of microbes over time within an institution, or country so as to be able to track resistance trends for a time period (Joshi 2010).

Once antibiogram data is collected appropriately and in a continuous manner it can be used to develop yearly trends that can be used to detect changes in susceptibility of bacterial isolates. This can serve many purposes in medical institutions such as, serve as a basis for empirical treatment, guide drug formulary decisions, and changes in prescribing and infection control practices. This information can then be used to develop intervention strategies by multi-sectoral entities (Halstead *et al.* 2004). Despite the fact that regional and global data can provide insight on the magnitude of drug resistance, it is best if local or even institutional data is available as this is more valuable to medical providers when managing infections (O'Brien 1997).

In order to better understand SSIs, as it relates to pathogen's antimicrobial susceptibility, and bacterial isolates diversity in surgical infections many studies are carried out frequently across the globe as susceptibility in microbes in the different regions varies. Giacometti *et al.* (2000) aimed to identify common pathogens in surgical wound infections and characterize the antimicrobial susceptibilities of the isolates. A retrospective study was carried out with 676 patients who underwent surgical treatment during a 6 year period. All patients that were included had presented signs and symptoms indicative of surgical wound infections within 60 days post-surgery. Cultures were taken from the patients, before antibiotic therapy, during antibiotic therapy and after antibiotic therapy. Data obtained showed that even though 963 pre-antibiotic treatment specimens were collected from the group of 676 individuals, 1060 bacterial strains were isolated from 614 individuals. A single etiologic agent was identified in 271 patients, multiple agents were found in 343, and no agent was identified in 62. A high preponderance of aerobic bacteria was observed. Among the common pathogens were *Staphylococcus aureus* (191 patients, 28.2%), *Pseudomonas aeruginosa* (170 patients, 25.2%), *Escherichia coli* (53 patients, 7.8%), *Staphylococcus epidermidis* (48 patients, 7.1%), and *Enterococcus faecalis* (38 patients, 5.6%). When the cultures were studied for antibiotic resistance it was found that more than 50% of the Enterobacteriaceae tested were resistant to ampicillin, while only a few (<20%) were resistant to the combination of amoxicillin and clavulanate. In addition, it was observed that most isolates were susceptible to ceftriaxone but more than 50% were resistant to cefazolin. In this study *S. aureus* was the most common cause of surgical wound infections, with Methicillin resistance being documented in 104 (54.4%) of 191 *S. aureus* isolates (Giacometti *et al.* 2000).

Similarly a study to identify antimicrobial patterns of isolates responsible for post-operative wound infections was conducted at the surgical wards of Obafemi Awolowo University Teaching Hospital Complex, in Nigeria for a 2 year period. Samples for cultures were obtained from the surgical sites of 89 hospitalized patients. Infections in abdominal wounds were most frequent accounting for 44.9%, followed by leg wounds, 18.0%. After isolation, identification and antimicrobial susceptibility screening of pathogens isolated, data gathered showed that bacterial pathogens were isolated from all specimens collected and *Candida spp*. were isolated from 12.4% of the samples. *Staphylococcus aureus* was the most recurrent organism isolated, accounting for 23 (18.3%) of a total of 126 isolates. *Pseudomonas aeruginosa* and Bacillus spp accounted for 11.1% each; *Escherichia coli* 10.3%; *Candida spp* 8.7%; Coagulase negative *staphylococci* 8.7%; *Pseudomonas spp* 6.3%; and *Serratia odorifera* accounting for 4.7% of total isolates. Multiple pathogens being isolated per infection. In general, resistance to the β-lactam antibiotics was above 98%, whereas more than 70% of isolates were resistant to erythromycin, fusidic acid and tobramycin. Must isolated were found to be multidrug resistant (Akinkunmi *et al.* 2014).

Patterns identified in seem to be similar regardless of the region. Likewise, the spectrum of antimicrobial resistant pathogens in large health care centers is similar to those found in small community hospitals. In a study conducted at a Midwest community hospital in the US, to look at the range of organisms isolated from surgical site infections, showed that of a total of 10,672 surgeries performed, 89 were identified as SSIs. *Staphylococcus aureus* was the most common pathogen (25.8%), followed by Enterobacteriaceae with (12.4%), *streptococci spp.* with (11.2%), *coagulase-negative staphylococci* with (10.1%), *enterococci spp.* with (7.9%), and *Pseudomonas aeruginosa* with (6.7%). Methicillin Resistant *Staphylococcus aureus* (MRSA) was isolated from 4.5% of the cases (Cantlon *et al.* 2006). Overall the results showed that the pathogen spectrum and emergence of MRSA from small community hospitals are comparable to those reported in studies conducted at large academic health care centers.

According the Center of Disease Control and Prevention the overall incidence of SSIs in the United States is estimated to be 2.8% of the total number of surgical procedures conducted (Barie 2002). However, this estimated value might be even larger as possibly under reporting might be occurring in instances of ambulatory surgical settings, were surgeons do not self-report infections that may occur under this circumstances.

HAI's are estimated to affect over 2 million patients annually in the United State, accounting for a great portion of morbidity and mortality cases. In an effort to estimate the magnitude of health facility related infections at US hospitals, a random sample of patients and hospitals were studied, findings show that approximately 5.7% of the 169,526 patients in 338 randomly selected U.S. hospitals developed a nosocomial infection. This implicating an estimated nationwide nosocomial infection rate among the 6,449 acute-care US hospitals to about 5.7% infections per 100 admissions (Haley *et al.* 1985). Nosocomial urinary tract infections accounted for the highest percentage of infections with 42% of the infections, followed by surgical site infections accounting for 24% (Haley *et al.* 1985).

Studies conducted in other countries, for instance Guatemala reports a baseline SSIs rates of 5% (Berg *et al*. 1995). In a study to determine the incidence of nosocomial and early surgical site infection in 1200 patients, at Roosevelt Hospital, a third level reference and University Hospital in Guatemala, results showed that 49/1200 (4.1%) patients showed clinical manifestations of infection, and out of this 77.6% were surgical site infections, showing an incidence of SSIs greater than that from developed countries (Cazali *et al.* 2008).

Considering that surgical site infections are directly associated to increase in pathogen antimicrobial resistance, information about the burden of these HAIs in developing countries is of dire importance. However, in a little to no data on the burden of SSIs is available in developing countries. In a review conducted to assess the epidemiology of endemic health-care-associated infection in developing countries, data showed that limited data is available in some regions but while on others there was none. The overall pooled prevalence of health-care-associated infections in developing countries was 5·5 per 100 patients, which was comparably high when compared with proportions reported from Europe and the USA. Surgical site infection were the leading infection in hospitals, with a cumulative incidence 5·6 per 100 surgical procedures, notably higher than proportions recorded in developed countries. Gram-negative bacilli was the most common isolate. Also noted was that few articles report antimicrobial resistance other than methicillin resistance *Staphylococcus aureus* isolate (Allegranzi *et al*. 2011).

Trends in the incidence of SSIs are monitored by the National Nosocomial Infections Surveillance system of the CDC. Data gathered shows that SSIs are the third most frequently reported nosocomial infection and are associated with morbidity, increase length of stay at hospital, and increase healthcare costs. The implementation of surveillance of antimicrobial resistance in Latin America was led by the World Health Organization for the Americas and Pan American Health Organization. The aim is to compile data for isolates and their susceptibility. In this region in 2014 only 19 countries in Latin America in addition to the US and Canada were participating, although English speaking countries from Central America had been invited to participate no data had been shared as yet. However, data gathered illustration that *E. coli*, *Klebsiella spp*, and *S. aureus* are resistant to more than 50% of commonly used antibiotics in some locations (WHO 2014b).

Although data for third world countries is limited, reviews of available literature have concluded that the burden of surgical site infections in developing countries is increasing. While the relative impact of antibiotic-resistant organisms globally are unknown, what is known is that they are prevalent worldwide. In first world countries such as Europe, methicillin-resistant *Staphylococcus aureus* accounts for up to 50% of *S. aureus* infections (Dulon *et al*. 2011). While data for low-income settings are not readily available, due to various limitations to conduct regular surveillance in resistant patterns, the little evidence that exist suggests a growing incidence of antibiotic-resistant pathogens from SSIs (Okeke *et al.* 2005).

Healthcare in Belize is provided through both public and private healthcare systems. The Ministry of Health (MOH) is the government agency that oversees the entire health sector and is also the largest provider of public health services in Belize. Apart from proving primary health care, the MOH also focuses in preventative health, hence the reason why surveillance systems are in place at all medical institutions. The aim of a surveillance system for HAIs is that data collected can be analyzed to identify and investigate trends of the magnitude of antimicrobial resistance and prevalence of SSIs in the country.

Justification

This analysis is important because no study of this kind has been carried out in the country, considering the morbidity and mortality rates of SSIs along with the increase in antimicrobial resistance in other parts of the world it is important to take a closer look at the situation in country. An analysis of this type is a starting point to create awareness of the antimicrobial crisis to relevant stakeholders within the Ministry of Health. This study can serve as a stepping stone to create a standard as it pertains to steps that need to be implemented by the health facilities and the MOH to tackle the problem.

Hypothesis

- The number of pathogens that are resistant to antibiotics is increasing with time.
- Over time, more pathogens will become multi drug resistant
- Infections due to multiple pathogens will be harder to treat with single antibiotics.

Objective

This retrospective study is aimed to characterize the etiology and antimicrobial susceptibility patterns of pathogens isolated from surgical infections at public medical facilities in the country for a 9 year period from 2009 – 2017.

Methodology

<u>Antibiogram Laboratory Experiment</u>

Understanding the antibiotic resistance/susceptibility patterns is critical in treating bacterial infectious diseases. In order to establish and understand the antibiogram in pathogens a laboratory experiment was carried out at the Teaching Laboratory for the Medical Laboratory Technology Program at the University of Belize under the assistance of Mr. Dio Mar Salazar. A Culture test was carried out followed by antibiogram test and pathogen identification.

Steps of Culture and Antibiotic Sensitivity Test:

After determining the presence of an infection, a culture sample is collected utilizing a swab. Careful technique while swabbing infected area during sample collection is key to avoid contamination. After sample is collected proper aseptic techniques are implemented to maintain pureness of the sample. Under the laminar flow chamber, culture material was inoculated on special nutrient culture medium. One was plated on Nutrient Blood agar and another on MacConkey agar plate. Blood agar contains 5% sheep blood, and used to cultivate fastidious organisms and determine the hemolytic capabilities of the organism. While MacConkey agar is used as a selective and differential culture medium, designed to isolate Gram-negative bacteria. Inoculation of media was done in quadrants, as the goal was to obtain pure plates were single colonies can be isolated. Inoculated culture media was then incubated for 24hrs at 37+-1^{o}C.

After the incubation process morphological description bacterial colonies was carried out. Following that Gram staining test was done, the pathogen was identified based their shape, arrangement, Gram's reaction and other cultural characteristics. After the pure culture establishment antimicrobial susceptibility/resistant patterns were carried out.

Antibiogram Test

Bacterial colonies from pure culture plates were used to prepare 1- McFarland standard, a method used to adjust the turbidity of bacterial suspension, to create a standard number of microbes. This was carried out so that when the antibiotic susceptibility is conducted the number of bacteria will be within a standardized range. A plate of Muller-Hinton agar was then inoculated by spread plate technique with 0.1 mL of the 1-McFarland standard of the test organisms. Small antibiotic containing discs were then placed into this bacteria inoculated medium, sterile conditions was key during this process, to avoid contamination. The culture was then incubated for 24 hours. After incubation, the zone of inhibition (diameter in mm) was measured for each antibiotics and for each test organism. There were four discs containing different antibiotics for test organism. The most effective antibiotic to inhibit the bacterial growth is chosen for treatment.

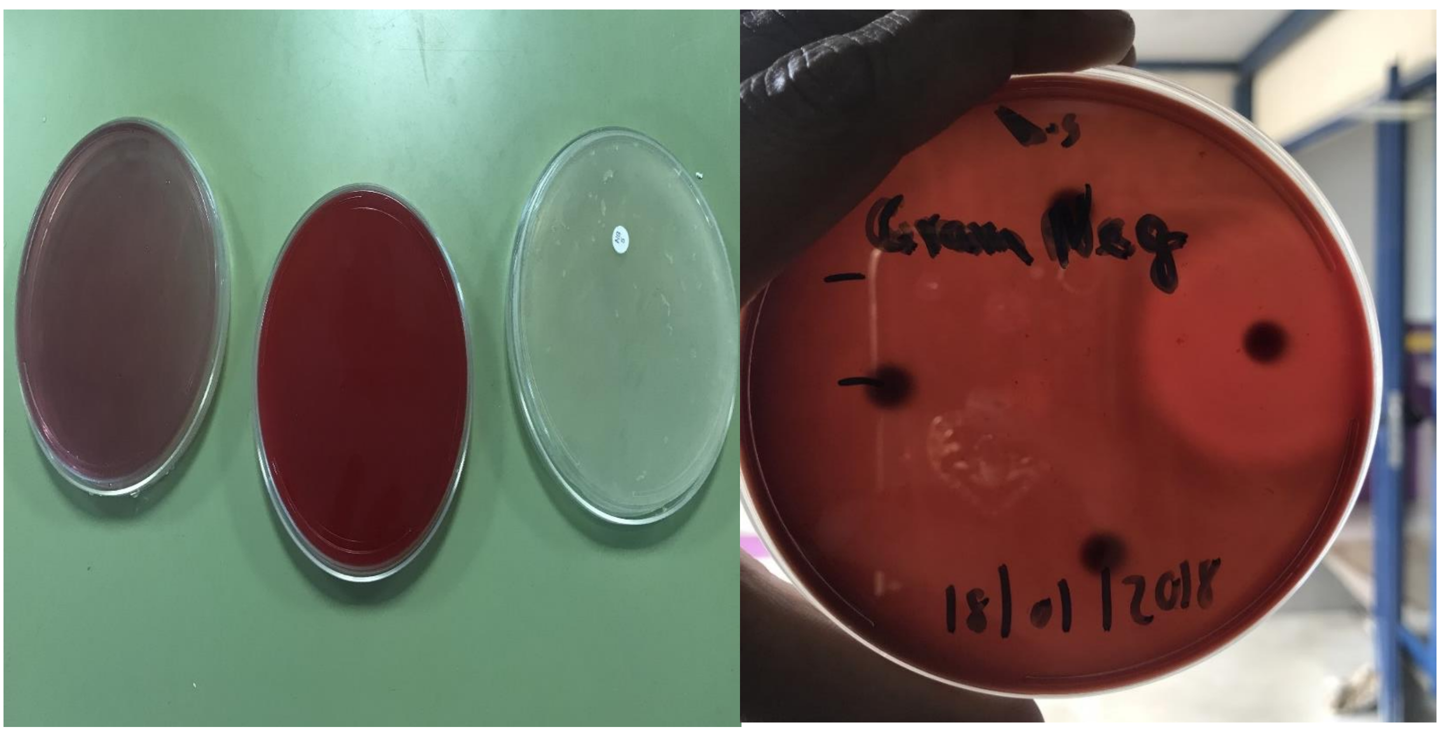


Figure1: Antibiogram Testing (a) Media for Culture and Antibiogram Test (b) Antibiogram test results

Depending on the diameter of growth inhibition the sensitivity of the organism to the different antibiotics was determined as, resistant, susceptible or intermediate. This is determined by using a zone diameter interpretive standards chart for determination of antibiotic sensitivity and resistant status by disc diffusion method (Hombach *et al.* 2013).

Identifying the bacteria

Using the McFarland Standard solution, 50 µl was pipetted in a Bis-Neg diagnostic plate which has 24 wells. Oil was added to one of the wells to identify if the pathogen was anaerobic. The plate was incubated for 24 hours. After incubation the results were recorded based on color changes in the different wells as seen in the picture below. This information was then added into an electronic data base that helps identify the bacteria. In this experiment the isolated pathogen was *Escherichia coli.*

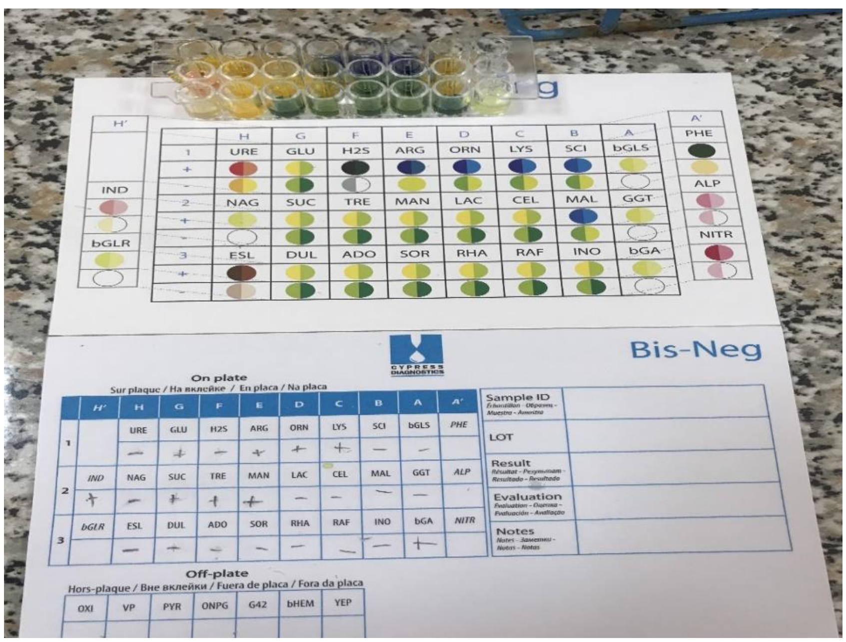


Figure 2: Bacterial Identification System for pathogen identification

Data Source

A descriptive study using raw data provide by the ministry of Health for a 9 years period, 2009-2017 was carried out. Data used was collected through the Belize Health Information System (BHIS), which is a network used at all public medical facilities under the Ministry of Health mandate. Raw data includes basic demography as well as the type of pathogens and antibiotic susceptibility results for various antibiotics. These are results for sputum samples collected from selected SSIs at public medical facilities throughout the country. The country's health system comprises a network of health facilities providing healthcare to the country's population of 368,310; and includes 4 regional hospital, 3 community hospital, and poly clinics. The four regional hospitals include Northern Regional Hospital (NRH), Western Regional Hospital (WRH) Southern Regional Hospital (SRH) and the Karl Heusner Memorial Hospital Authority (KHMHA) which serves a dual role both as the Central Regional Hospital and the National Referral Hospital for the country. The data provided by MOH utilizes a database on pathogens cultured at the Central Medical Laboratory (CML) and made available through BHIS.

Data collection through the BHIS allows population-based, health services, and records-based data to be available to users countrywide. It connects the Ministry of Health with every registered citizen who accesses public services, hospital, lab, and pharmacy. It is comprised of a set of interdependent modules surrounding the central electronic record. Modules of BHIS includes: Admission and Discharge and Transfer, Clinician Order Entry, Laboratory, Supply Chain Management, Pharmacy, and Human Resources, Demographic data. To date, BHIS has been installed and functioning in more that thirty-three facilities country-wide. Data is supervised, reconciled and managed by the Epidemiology Unit.

Flow chart below shows a graphical view on data collection through BHIS at the different levels in at all health facilities managed by the MOH.

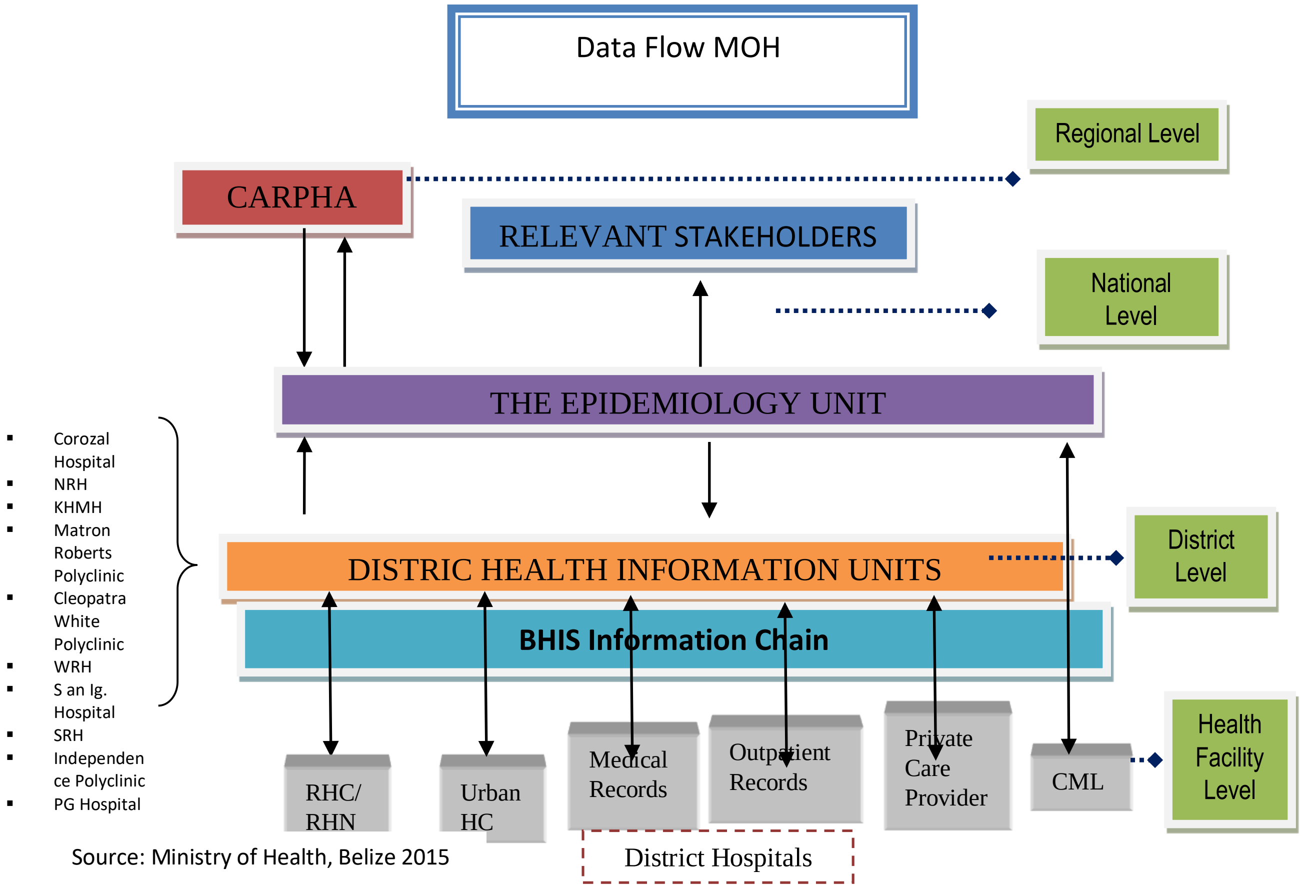


Figure 3: Data Flow Chart using MOH, BHIS

The study population included any person who visited any of the public medical facilities and underwent any type of surgical procedure during the period 2009-2017 and acquired an infection 30 days after the procedure. Data included selected Surgical Site Infections, namely Abscess, Amputation, Appendectomy, Cesarean, Delivery, Fracture reduction, Laparotomy, Hysterectomy, Foreign body removal, Cholecystectomy, Endoscopy.

Analysis

After raw data was collected, and extracted the initial data cleaned out and verified for any repetition or duplication. The Raw data was provided in a Microsoft Excel spread sheet with no order or arrangement since it came from different centers in a chronological order. The data was sorted, compiled and arranged in an orderly manner. Duplicate entries, pseudo entries, missing data and any other atypical errors caused by errors of data entry were removed. Data used for antibiotic susceptibility testing were sorted and cases with no antibiogram results were discarded for this section of the analysis. Statistical analysis using Microsoft excel and SPSS version 16.0 was carried out. Univariate descriptive analysis of the dataset was conducted on various epidemiological and demographical variables for the time period. General statistics such as frequency tables, rates, and proportions were carried out and depicted in graphs. Cross tabs were carried out in SPSS to analyze the susceptibility patterns of pathogens to the different antibiotics.

Results

Data compiled for analysis was collected through the Belize Health Information Unit. This comprised of 630 infections for the period 2009- 2017. From the total of 630 cultures only 50% (315) had pathogens isolated. Descriptive analysis was carried out with data set of 315 surgical site infections that were positive for isolates for several variables, including distribution per year, gender, age-group, pathogens isolated and susceptibility analysis of isolates to antimicrobials. Results are presented in two sections below, Section I, is has general descriptive analysis of demographic information and distribution of cases, while Section II contains results for antimicrobial susceptibility analysis of pathogens.

Section 1: Demography and Distribution

A total of 630 infection resulting from a surgical procedure were captured for the period 2009 to 2017. From the 630 culture samples, 50% (315) had pathogens isolated, and the remaining 50% (315) had no organisms identified.

Table1: Number of Surgical Site Infections for 2009-2017

Year	# of infections
2009	15
2010	17
2011	33
2012	67
2013	135
2014	90
2015	98
2016	86
2017	89
Grand Total	**630**

An increase in the number of infections can be seen throughout the years, with the year 2013, 2014 and 2015 accounting for the biggest proportion of infections through the nine year period, with 21.4%, 14.3% and 15.5% respectively.

Table 2: Bacterial Isolates Recovered From Surgical Site Infections

Organisms	No.	(%)
Acinetobacter spp	3	0.88
Citrobacter spp	3	0.88
Enterobacter spp	22	6.45
Enterococcus fecalis	6	1.76
Esherichia coli	60	17.60
Klebsiella spp	46	13.49
Morganella morgani	5	1.47
Proteus spp	18	5.28
Providencia spp	7	2.05
Pseudomonas aeruginosa	33	9.68
Serratia marcessens	1	0.29
Staphylococcus aureus	106	31.09
Staphylococcus epidermidis	17	4.99
Streptococcus group B	2	0.59
Other Bacterial Pathogens	10	2.93
Grand Total	**339**	**99.41**

From the 315 positive culture samples, a single pathogen was isolated from 294 (93.3%) patients and multiple pathogens were identified from 21(6.7%) cases. A total of 341 pathogens were isolated, comprising of 15 different organisms. *Staphylococcus aureus* was the pathogen that was most frequently isolated with 31.09%. *Escherichia coli*, *Klebsiella spp*, *Pseudomonas aeruginosa* and *Enterobacter spp.* respectively accounted for 17.6%, 13.49%, 9.68% and 6.45% of the total number of isolates. Bacterial isolates were isolated from 99.41%, while fungal Candida albicans was isolated from 0.59% of cases.

Table 3: Aerobic Gram Positive Organisms

Organism	No	(%)
Enterococcus fecalis	6	1.76
Staphylococcus aureus	106	31.09
Staphylococcus epidermidis	17	4.99
Streptococcus group B	2	0.59
	131	**38.42**

Table 4: Aerobic Gram Negative Organisms

Organism	No	(%)
Esherichia coli	60	17.60
Pseudomonas aeruginosa	33	9.68
Klebsiella spp	46	13.49
Morganella morgana	5	1.47
Proteus spp	18	5.28
Providencia spp	7	2.05
Serratia marcessens	1	0.29
Enterobacter spp	22	6.45
Citrobacter spp	3	0.88
Acinetobacter spp	3	0.88
	198	**58.06**

Aerobic gram positive bacteria accounted for 38.42% (131) of the total number of organisms isolated (341). *Staphylococcus aureus* constituted of 80.9% of the gram positive pathogens. Aerobic gram negative bacteria accounted for 58.06% of the total number of isolates. *Escherichia coli*, *Klebsiella spp* and *Pseudomonas aeruginosa* constituted 30.3%, 23.2% and 16.7% of the gram negative pathogens respectively. Other bacterial pathogens isolated accounted for 2.3%.

Table 5: Sex Distribution of Patients

Gender	Frequency	(%)
Male	101	32.1
Female	214	67.9
Total	**315**	**100.0**

The highest proportion of cases are females with 67.9 %, while males accounted for the lesser portion with 32.1%.

Table 6: Age-group of patients from whom pathogens were isolated

Age group	No.	(%)
0-9	26	8.3
10-19	50	15.9
20-29	94	29.8
30-39	37	11.7
40-49	39	12.4
50-59	28	8.9
65+	41	13.0
Total	**315**	**100**

The age-group with the highest number of isolates from the 315 culture samples collected were those from 20-29 year with 94 (29.8 %), followed by those in the age-group 10-19 years with 50 (15.9%), and those with 65+ years with 41(13%).

Table 7: Cases Distributed by District of Residence

District	No.	(%)
Corozal	6	1.9
Orange Walk	17	5.4
Belize	143	45.4
Cayo	95	30.2
Stann Creek	32	10.2
Toledo	22	7.0
Total	**315**	**100**

Belize district comprised of the majority of cases with 45.4% (143), followed by the Cayo district with 30.2% (95) and Stann Creek district with 10.2% (32). 58.4% being from urban communities and 41.58% from the rural communities.

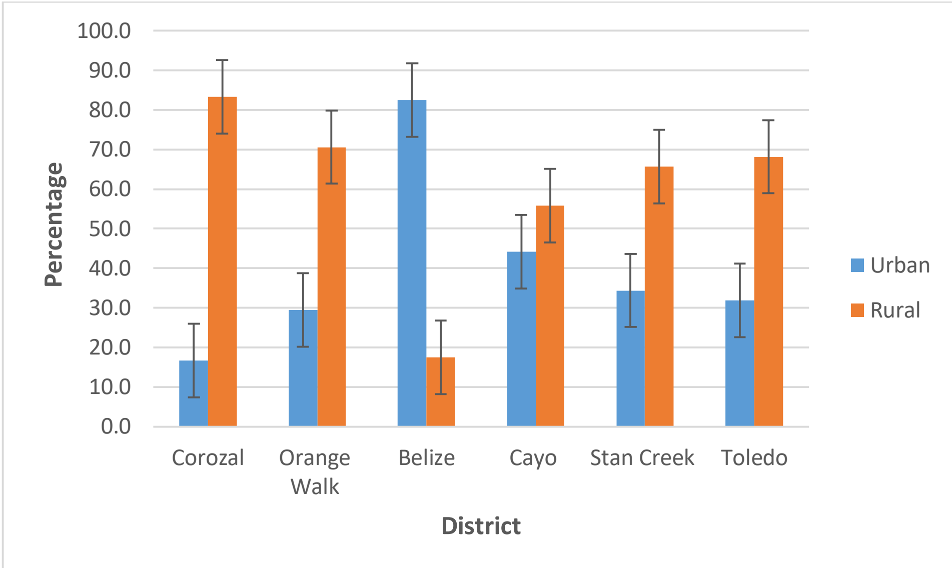


Figure 4: Percentage Distribution of Cases by Urban and Rural Communities per District

In the Belize district the highest proportion of cases were from the urban area with 82.5% and the remaining 17.5% cases from rural Belize. In five of the six districts the majority of cases were from people who reside in rural communities.

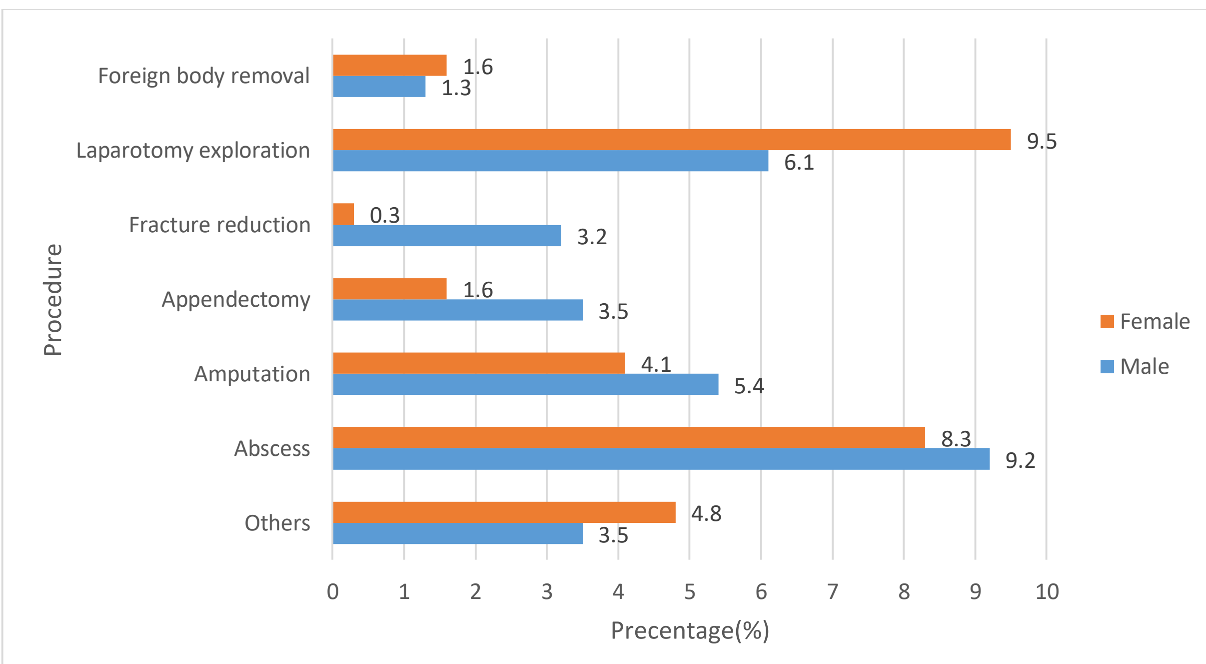


Figure 5: Type of Surgical Procedure by Gender

Abscess accounted from 17.5 % (55) of the positive infected surgical procedures, Laparotomy exploration with 15.6 % (49) and Amputations with 9.5% (30). Males accounted for a higher percentage of the Abscess infections than females with 9.2% of a total 17.5%. However when looking at Laparotomy exploration, females accounted for a higher percentage of 9.5% of a total 15.6%. In infected Amputations males accounted for the highest proportion with 5.4% of a total 9.5%. In Fracture reduction males accounted for the majority of infected cases with 3.2% while females accounted for 0.3%.

Table 8: Female Related Surgical Procedures

Type of Surgery	(%)
Cesarean	28.3
Delivery	5.1
Hysterectomy	4.4
Percentage Total	**37.8**

Female related surgical procedures accounted for 37.8% of the total procedure types. With Cesarean surgeries accounting for the highest percentage in the overall number of surgical procedures with 28.3%.

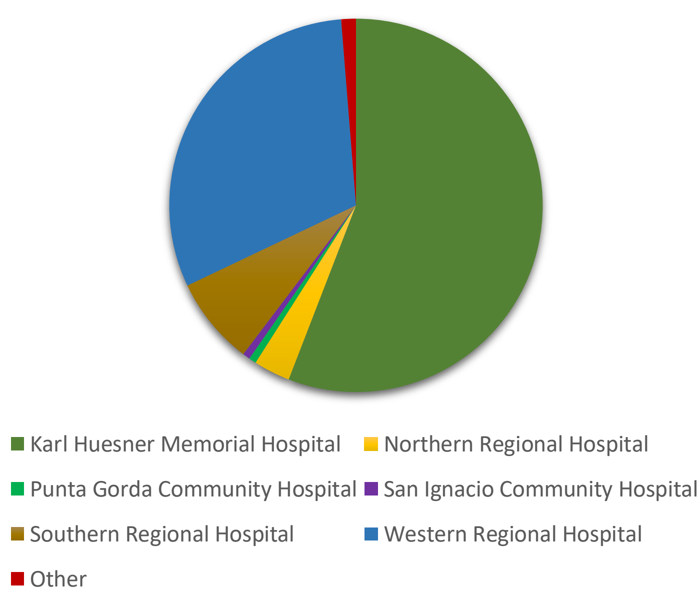
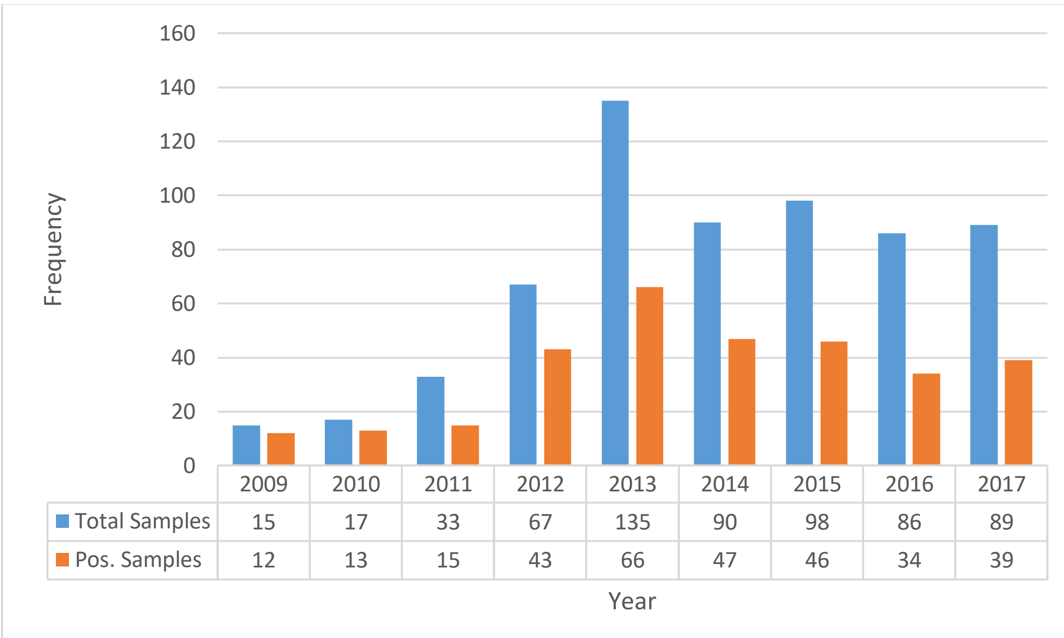


Figure 6: Positive Culture Samples by Facility

Karl Huesner Memorial Hospital and Western Regional Hospital accounted for highest percent of positive samples collected with 55.9% (176) and 30.8% (97) respectively. The smallest proportion of samples are seen in the community hospitals, being Punta Gorda Community hospital, San Ignacio Community Hospital. Under the “other” category, BCVI and Matron Roberts Health center was included with two samples each contributing to 1.3% (4) of the positive samples.



	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total Samples	15	17	33	67	135	90	98	86	89
Pos. Samples	12	13	15	43	66	47	46	34	39

Figure 7: Total Number of Samples versus Number of Positive Samples

For the year 2009, 80 % (12) of the infections were positive, in 2010 76.5% (13), in 2011 45.5% (15), in 2012 64.2% (43), in 2013 48.9 % (66), in 2014 52.2% (47), in 2015 46.9% (46), in 2016 39.5% (34) and in 2017 43.8% (39). Although in the year 2013 accounts for the highest proportion of positive samples in the overall nine year period, the year 2009 and 2010 had the highest proportion of positive culture samples when compared to samples collected per year.

Section 2: Antimicrobial Sensitivity Analysis

From the 341 pathogens isolated 5.9% (20) had no results for sensitivity analysis therefore, for the purpose of sensitivity results unscreened isolates were disregarded and the data set for pathogen sensitivity encompassed 321 isolates.

Table 9: Zone diameter interpretive standards chart for the determination of antibiotic Sensitivity status by disk diffusion method

Antibiotic	Standard Concentration	Spectrum of Activity(mm)		
		R (resistant)	I (intermediate)	S (susceptible)
Amikacin *Enterobacteriaceae *P.aeruginosa *Acinetobacter *Staphylococcus spp.	30µg	≤ 14	15-16	≥17
Amoxicillin /Clavulanate * Enterobacteriaceae	20/10µg	≤ 13	14-17	≥18
*Staphylococcus spp.		≤ 19	---	≥20
Ceftazidime *P.aeruginosa *Acinetobacter *Staphylococcus spp.	30µg	≤ 14	15-17	≥18
*Enterobacteriaceae		≤ 17	18-20	≥21
Ciprofloxacin *Enterobacteriaceae *P.aeruginosa *Acinetobacter *Staphylococcus spp. *Enterococcus spp.	5µg	≤ 15	16-20	≥21
Erythromycin *Staphylococcus spp. *Enterococci spp.	15µg	≤ 13	14-22	≥23
*S. pneumoniae and other Streptococcus spp.		≤ 15	16-20	≥21
Gentamicin *Enterobacteriaceae *P.aeruginosa *Acinetobacter *Staphylococci	10µg	≤ 12	13-14	≥15
Imipenem *Acinetobacter	10µg	≤ 13	14-15	≥16

*Enterobacteriaceae		≤ 19	20-22	≥23
*P.aeruginosa		≤ 15	16-18	≥19
Tetracycline *P.aeruginosa *Staphylococcus spp. *Enterococci	30µg	≤ 14	15-18	≥19
Trimethoprim/Sulphamethoxzole *Enterobacteriaceae *P.aeruginosa *Acinetobacter *Staphylococcus spp.	1.25/23.75µg	≤ 10	11-15	≥16
Vancomycin enterococci *****Enterococcus spp.	30µg	≤ 14	15-16	≥17

The above table is used when conducting an antibiogram to determine if the pathogen identified is either resistant, susceptible to the antibiotic screened or intermediate. This is based on the concentration of the antibiotic used and the diameter of the area of inhibition.

Table 10: Sensitivity Profile of Bacterial Isolates from Surgical Site Infections

Organism	No. of Isolates	No. Isolates resistant (No. tested) % resistant									
		Ami	Amx/Cl	Cefa	Cipr	Eryt	Gent	Imip	Tetra	Trim/Sulph	Vanc
Acinetobacter spp	3	1(3) 33.3%	---	3(3) 100%	2(2) 100%	---	1(2) 50%	0(3) 0%	0(3) 0%	2(2) 100%	---
Citrobacter spp	3	0(3) 0%	0(1) 0%	0(3) 0%	0(2) 0%	---	0(3) 0%	0(2)	---	---	---
Enterobacter spp	22	1(22) 4.5%	10(10) 100%	7(16) 43.8%	4(17) 23.5%	---	4(19) 21.1%	0(13) 0%	1(5) 20%	8(14) 57.1%	---
Enterococcus fecalis	6	---	---	---	1(4) 25%	1(3) 33.3%	2(2) 100%	---	4(6) 66.7%	---	0(3) 0%
Esherichia coli	60	3(56) 5.4%	2(25) 8%	2(34) 5.9%	26(54) 48.1	1(1) 100%	14(52) 26.9%	0(35) 0%	15(22) 68.2%	16(31) 51.6%	---
Klebsiella spp	46	2 (43) 4.7%	7(21) 33.3%	1(22) 4.5%	15(44) 34.1%	---	23(41) 56.1%	0(29) 0%	6(9) 66.7%	20(32) 62.5%	---
Morganella morgani	5	0(5) 0%	1(1) 100%	1(5) 20%	0(4) 0%	---	0(5) 0%	0 (4) 0%	1(1) 100%	2(4) 50%	---
Proteus spp	18	0(17) 0%	1(9) 11.1%	0(15) 0%	1(14) 7.1%	0(1) 0%	2(16) 12.5%	0(12) 0%	3(3) 100%	2(11) 18.2%	---
Providencia spp	7	0(7) 0%	5(5) 100%	0(6) 0%	2(7) 28.6%	---	0(5) 0%	0(4) 0%	1(2) 50%	1(4) 25%	---
Pseudomonas aeruginosa	33	4 (32) 12.5%	3(3) 100%	7(30) 23.3%	1(30) 3.3%	---	5(28) 17.9%	1(20) 5%	3(3) 100%	1(1) 100%	---
Serratia marcessens	1	0(1) 0%	---	0(1) 0%	0(1) 0%	---	0(1) 0%	0(1) 0%	---	---	---
Staphylococcus aureus	106	1 (8) 12.5%	9(16) 56.3%	---	36(94) 38.3%	64(103) 62.1%	11(95) 11.6%	3(5) 60%	21(92) 22.8%	7(88) 8%	5(93) 5.4%
Staphylococcus epidermidis	2	---	---	---	1(1) 0%	2(2) 100%	1(1) 100%	---	1(2) 50%	0(1) 0%	0(2) 0%
Other Bacterial Pathogens	9	1 (4) 25%	0(1) 0%	2(5) 40%	3(5) 60%	2(3) 66.7%	1(5) 20%	0(1) 0%	3(5) 60%	2(6) 33.3%	0(2) 0%
Total	**321**	**13(201) 6.5%**	**38(92) 41.3%**	**23(140) 16.4%**	**92(279) 33%**	**70(113) 62%**	**64(275) 23.3%**	**4(129) 3.1%**	**59(153) 38.6%**	**61(194) 31.4%**	**5(100) 5%**

(--- not tested for antibiotic) Amikacin (Amik), Amoxicillin /Clavulanate (Amx/Cl), Ceftazidime (Cefa), Ciprofloxacin (Cipr), Erythromycin (Eryt), Gentamicin (Gent), Imipenem (Imip), Tetracycline (Tetra), Trimethoprim/Sulphamethoxzole (Trim/Sulph), Vancomycin enterococci (Vanc)

The sensitivity of the pathogens varied, with most being multi-drug resistant, with the exception of *Serratia marcessens and Citrobacter spp*, which were not resistant to any of the antibiotics screened.

Table 11: Multi-drug resistant strains of top three isolates

No Antibiotics Resistant	*E. coli* (n=60)	*S. aureus* (n=106)	*Klebsiella spp* (n=46)
2	9	31	12
3	6	14	7
4+	4	6	6
Total	**19**	**51**	**25**

S. aureus has 51 (49.1%) isolates that show resistance to 2 or more antibiotics, while 54.3% of *Klebsiella spp* and 19 of *E. coli* isolates were resistant to two or more of antibiotics tested.

The highest percentage of isolates were resistant to Erythromycin (62%), followed by Amoxicillin /Clavulanate (41.3%). More than 30% of the isolates were resistant to Ciprofloxacin, Tetracycline and Trimethroprim/Sulphamethoxzole.

Table 12: Sensitivity Analysis for Top Five Isolates

Organism	No. of Isolates	Imip	Tetra	Ami	Amx/Cl	Trim/Sulph	Eryt	Cipr	Vanc
Enterobacter spp	22	0(13) 0%	1(5) 20%	1(22) 4.5%	10(10) 100%	8(14) 57.1%	---	4(17) 23.5%	---
Esherichia coli	60	0(35) 0%	15(22) 68.2%	3(56) 5.4%	2(25) 8%	16(31) 51.6%	1(1) 100%	26(54) 48.1%	---
Klebsiella spp	46	0(29) 0%	6(9) 66.7%	2(43) 4.7%	7(21) 33.3%	20(32) 62.5%	---	15(44) 34.1%	---
Pseudomonas aeruginosa	33	1(20) 5%	3(3) 100%	4(32) 12.5%	3(3) 100%	1(1) 100%	---	1(30) 3.3%	----
Staphylococcus aureus	106	3(5) 60%	21(92) 22.8%	1(8) 12.5%	9(16) 56.3%	7(88) 8%	64(103) 62.1%	36(94) 38.3%	5(93) 5.4%

Enterobacter spp sensitivity analysis show that they are more resistant to Amoxicillin/Clavulanate with 100% isolates tested being resistant, followed with 57.1% isolates resistant to

Trimethroprim/Sulphamethoxzole. However this bacteria was less resistant to Imipenem and Amikacin with 0% and 4.5% isolates being resistant, respectively.

Escherichia coli were more resistant to Erythromycin and Tetracycline with 100% and 68.2% respectively. This bacteria were less resistant to Imipenem and Amikacin with 0% and 5.4% respectively.

Klebsiella spp were more resistant to Tetracycline and Trimethroprim/Sulphamethoxzole with 66.7% and 62.5% respectively. They were less resistant to Imipenem and Amikacin with 0% and 4.7% respectively.

Pseudomonas aeruginosa were more resistant to Tetracycline, Amoxicillin/Clavulanate and Trimethroprim/Sulphamethoxzole, testing 100% resistant for all isolates tested in each. However they were less resistant to Ciprofloxacin and Imipenem with 3.3% and 5% respectively.

Staphylococcus aureus, sensitivity profile showed greater resistance to Erythromycin, Imipenem and Amoxicillin/Clavulanate with 62.1%, 60% and 56.3% respectively. They were less resistant to Vancomycin and Trimethroprim/Sulphamethoxzole, with 5.4% and 8% respectively.

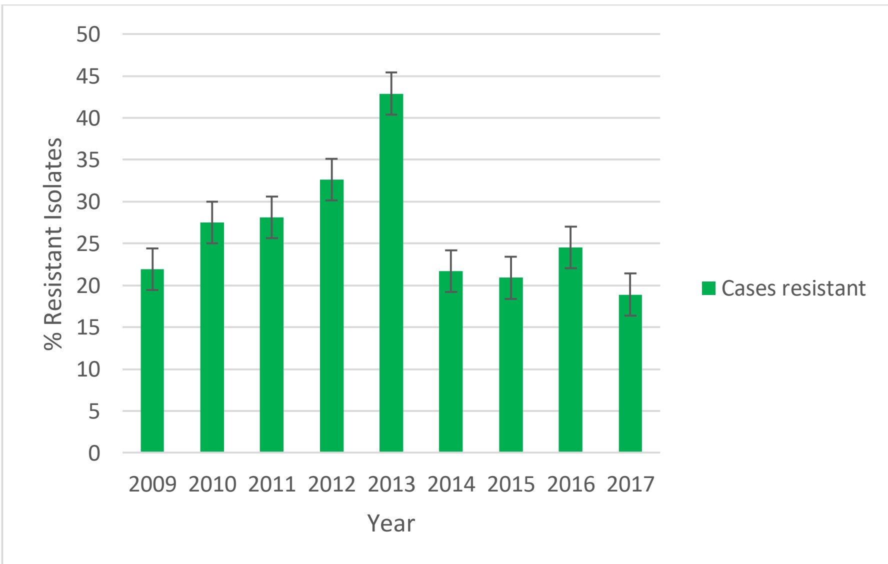
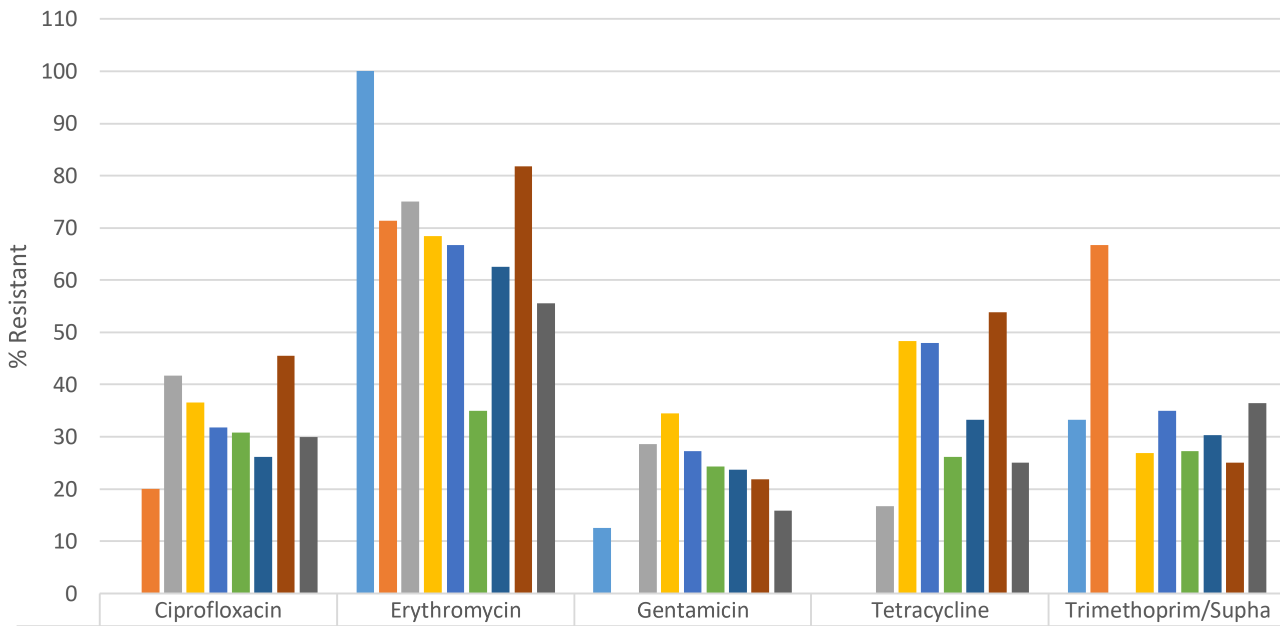


Figure 8: Percentage Pathogens Resistant per Year

A gradual increase in percentage of isolates resistant to antibiotics screened can be seen from 2009-2013 with a peak in 2013, however from 2014-2017, no such increase is observed.



	Ciprofloxacin	Erythromycin	Gentamicin	Tetracycline	Trimethoprim/Supha
2009	0	100	12.5	0	33.3
2010	20	71.4	0	0	66.7
2011	41.7	75	28.6	16.7	0
2012	36.6	68.4	34.5	48.3	26.9
2013	31.8	66.7	27.3	48	35
2014	30.8	35	24.3	26.1	27.3
2015	26.2	62.5	23.7	33.3	30.3
2016	45.5	81.8	21.9	53.8	25
2017	30	55.6	15.8	25	36.4

Antibiotic

Figure 9: Percentage Isolates Resistant to Diverse Antimicrobials per Year

A slight increase in the number of pathogens resistant to antimicrobials can be see per year, although a fluctuation can be seems to increases and decreases over the years. A larger percentage of microbes are resistant to Erythromycin ranging from 100% resistant to 35% resistant, in the case of the antibiot0ic Trimethoprim/ sulphamethoxaloe percentage of pathogens resistant range from 66.7 to 0 % resistant. Percentage pathogens resistant to Ciprofloxacin range from 45.5 to 0%

resistant. Tetracycline ranges from 53.8 to 0% resistant and Gentamicin percentage resistant range from 34.5 to 0% accounting for the smallest percentage of isolates resistant.

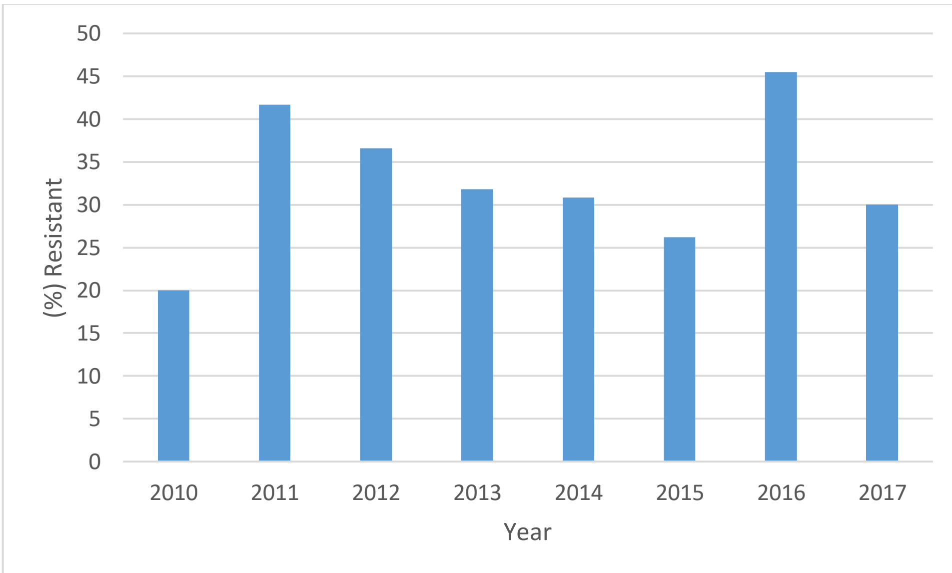


Figure 10: Percentage Isolates Resistant to Ciprofloxacin per year

From the year 2010 to 2017 more than 20% of isolates were resistant to Ciprofloxacin.

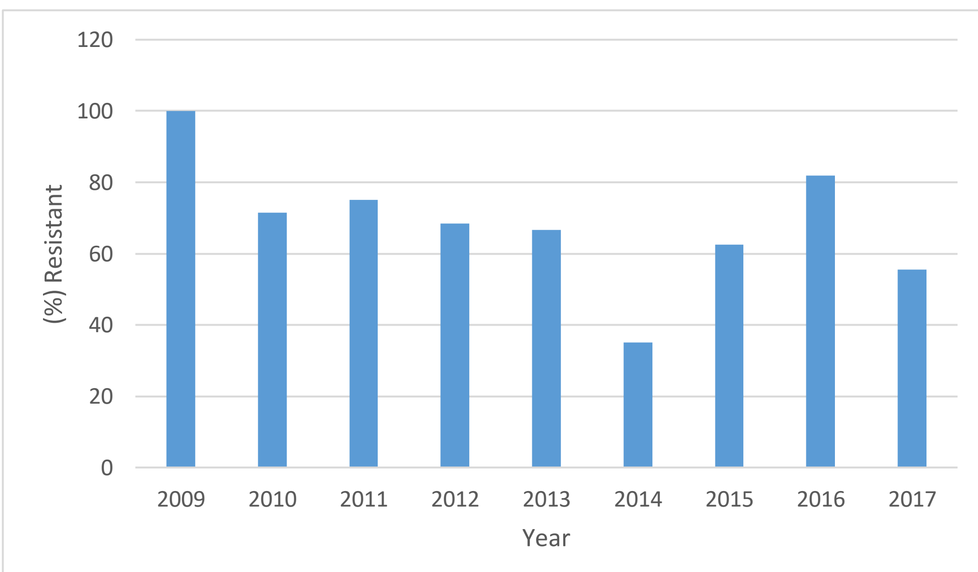


Figure 11: Percentage Isolates Resistant to Erythromycin per year

More than 35% of isolates were resistant to Erythromycin through the entire 9 year period of study.

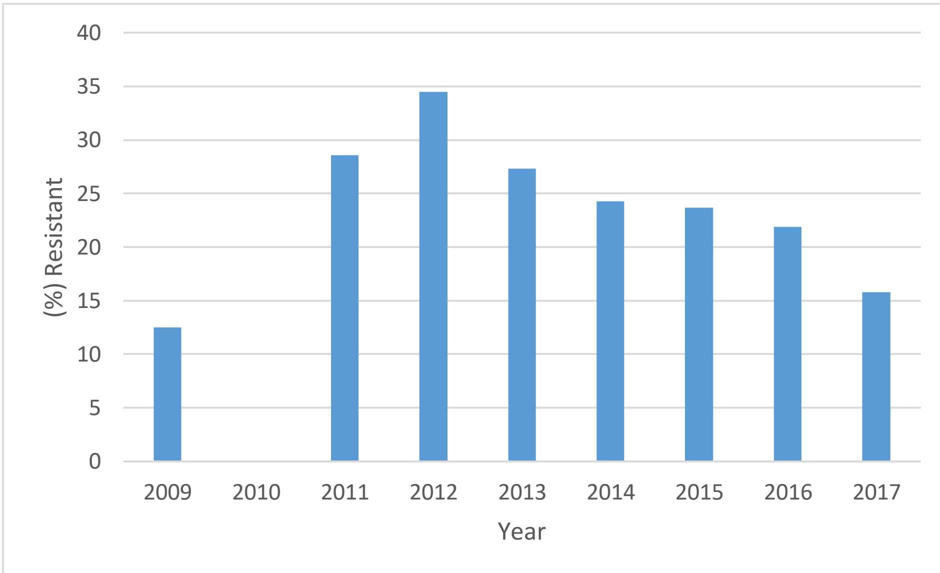


Figure 12: Percentage Isolates Resistant to Gentamicin per year

From 2011 to 2017 an increase in proportion of isolates were resistant to Gentamicin, with over 15% of isolates testing resistant.

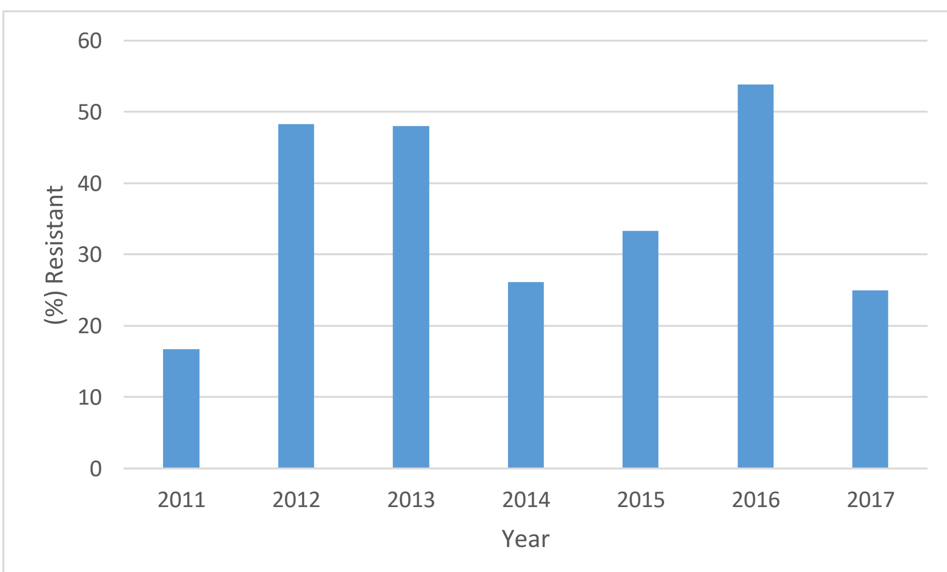


Figure 13: Percentage Isolates Resistant to Tetracycline per year

From 2011 to 2017 an increase in resistance to tetracycline is seen.

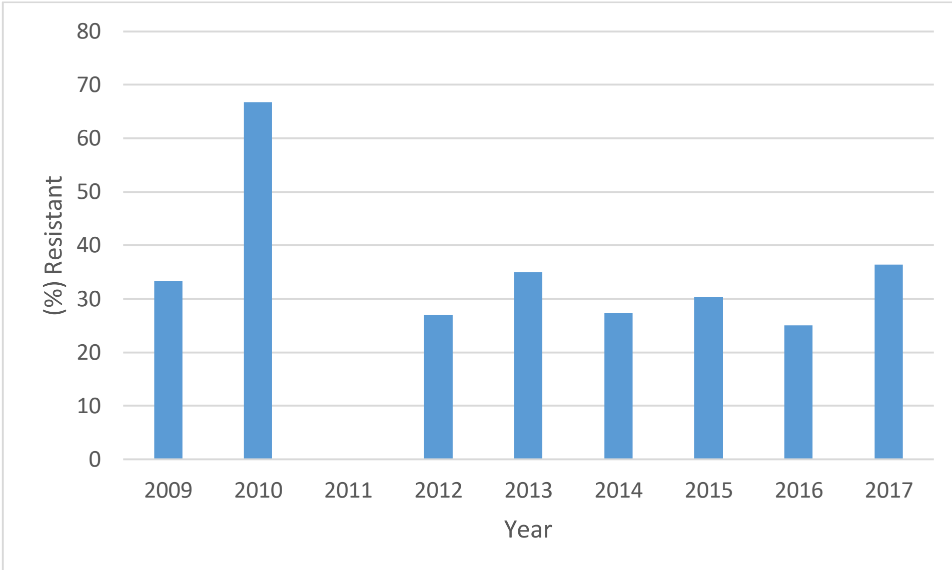


Figure 14: Percentage Isolates Resistant to Trimethoprim/Sulphamethoxaloe per year

With the exception of the year 2011, over 25% of isolates were resistant to Trimethroprim /Sulphaethozaloe.

On the graphs below, the analysis of resistance pattern of *E.coli* and *S. aureus* to Gentamicin, Ciprofloxacin and Trimethroprim/Sulphaethozaloe show no defined patterns of resistance, as it a constant fluctuates can be seen thought the years.

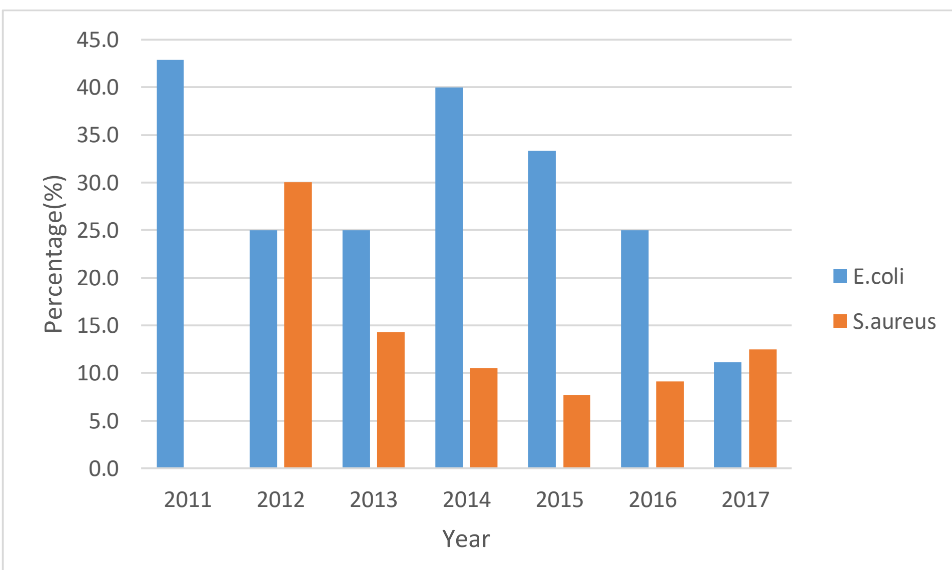


Figure 15: Resistance patters of *E.coli* and *S. aureus* to Gentamicin

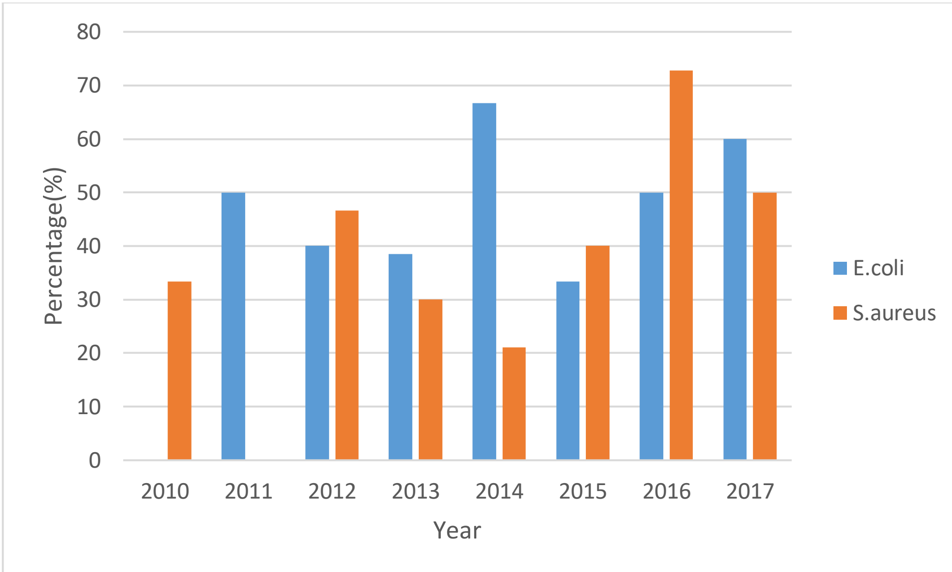


Figure 16: Resistance patters of *E.coli* and *S. aureus* to Ciprofloxacin.

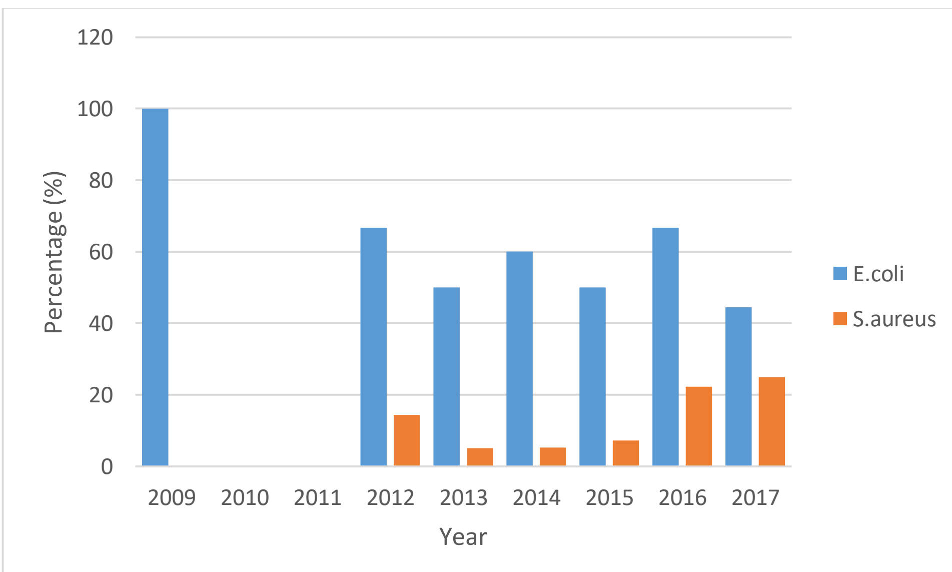


Figure 17: Resistance patters of *E.coli* and *S. aureus to* Trimethroprim/Sulphaethozaloe

Discussion

The study provides an insight of the major causative pathogens of post-operative surgical site infections and their sensitivity profile, throughout the country. For bacterial infections to be successfully managed, early identification of bacterial pathogens along with the selection of effective antibiotic are key. Antibiotics are one of the main players in modern medical care as it plays a major role as both prophylaxis and treatment of infectious diseases (Abula and Kedir 2004).

Findings showed that the year with the highest proportion of surgical infections was in the year 2013 with the highest surgical site infections accounting for 21.4% of the infections for the 9 year period of study. Throughout this study period an increase on the number of surgeries that resulted in an infection can be seen. However, this could be attributed to an increase in the number of surgeries in that year.

Of the total number of culture samples that were collected and tested 50% were positive for isolates, with the next half yielding no bacterial growth. Past studies show that potential causes of culture-negative surgical site infections could be attributed to prior antimicrobial therapy; the presence of fastidious or slow-growing microorganisms such as mycobacteria, Mycoplasma spp., and Legionella spp.; common infection caused by bacteria may be dismissed as contaminants of samples (Rasnake and Dooley 2006). However, they may be the actual causative agent of the infection at surgical site.

Most of the infections had a single pathogen isolated (93.3%) while 6.7% were polymicrobial infections. This is similar to the findings from Benito *et al.* (2014),where they reported 82.8% of the infections were mono-microbial. However a study by Akinkunmi *et al. (*2014), showed that 43.8% of the infections in their study were polymicrobic in nature.

Staphylococcus aureus and *Escherichia coli* were the most frequently isolated organisms from SSIs with 31.9% and 17.6% respectively. These findings are similar to those of other studies which reported *Staphylococcus aureus* and *Escherichia coli* as the primary microorganism infecting surgical wounds. Another study done in Africa reported 24.3% and 23.4% of their SSIs were positive for *Escherichia coli* and *Staphylococcus aureus* respectively (Amare *et al.* 2011). Furthermore, Manian *et al.* (2003) reported that 48% of the SSIs in their study were due to *S. aureus*, thus accounting for the most frequent isolate in their study. The abundance of *Staphylococcus aureus* in SSIs can be attribute to the invasive properties of the bacteria. The fact that *S. aureus* is a normal microbiota of the skin, could be a major contributor for the entry of the pathogen into the surgical wound during a procedure (Kluytmans *et al.* 1997).

The surgical procedure which constituted for the highest number of infections was cesarean-section followed by abscess and amputations. Female related procedures, such as cesarean section, delivery and hysterectomy accounted for 37.8% of SSIs. This can be directly correlated to the fact that the highest proportion of cases were females which accounted for 67.9% of the study population. The age group that was mostly affected were those from 20-29 years.

The current findings showed that 58.06% of SSIs were due to Gram negative bacteria and 38.4% of SSIs were due to Gram positive bacteria showing a predominance of Gram negative bacterial isolates in SSIs. This is comparable with a study done by Gelaw *et al.* (2013) on surgical infections acquired at hospitals which reported 69.4% Gram negative bacteria and 30.6% Gram positive bacteria.

The Belize District accounted for the highest proportion of cases, 45.4% of all SSIs were from the Belize District, of which 82.5% being from the urban areas. When looking at place of encounter, the Karl Huesner Memorial Hospital accounted for 55.9% of cases seen and this can be due to the fact that KHMH is the main public hospital in Belize city as well as it due to its dual function as both the National Referral Hospital for the country as well as the district hospital of Belize District. A gradual increase in percentage of isolates resistant to antibiotics screened was observed from 2009-2013. However, from 2014-2017, no such increase is observed. This could be associated, increase in personal therefore more monitoring, as well as changes in polices and treatment processes undertaken by the Ministry of Health.

There is no clear trend in antibiotic susceptibility/resistance patterns for the pathogens studied during the period of study in Belize, antimicrobial sensitivity of pathogens varied, however results showed that majority isolates were multi-drug resistant, with most of the isolates being resistant to at least five of the antibiotics used during antimicrobial sensitivity testing. The highest percentage of resistance was seen for Erythromycin (62%) of isolates screened. Followed by 41.3% being resistant to β-Lactam antibiotic, Amoxicillin /Clavulanate. This resistance patterns are similar to those obtained in other studies, were similar resistance patterns are seen for β-Lactam antibiotics with 59.3% resistance in a study by Bastola *et al.* (2017). The high resistance patterns to β-lactam can be because these antibiotics are the most commonly used antibiotics and resistant pattern have been reported in various studies (Desta *et al.* 2002). Additionally, more than 30% of the isolates were resistant to Ciprofloxacin, Tetracycline and Trimethroprim /Sulphamethoxzole.

The study showed that many of the isolates of *Staphylococcus aureus* were resistant to a range of antibiotics used in this study, with 51(49.1%) being reistant to two or more antibiotics. This is of concern as Methicillin-resistant *Staphylococcus aureus* is a major risk factor to many infections. The highest proportion or *S. aureus* were resistant to Erythromycin 62.1% and Imipenem 60%. This is similar to an earlier study where 60% of the isolates were resistant to Erythromycin by Piatkowska *et al.*(2012).

In this study only 5.4% of *S.aureus* isolates were resistant to Vancomycin. Although Vancomycin is usually used as initial empirical therapy in patients to treat patients with Gram-positive organisms, recent research suggests that the efficiency of Vancomycin to treat infections caused by *Staphylococcus aureus* is not as effective. Due to the evolution of organisms to antibiotics uses, *S. aureus* strains are now exhibiting increased resistance to Vancomycin (McGuinness *et al.* 2017). All the isolates of *Escherichia coli* were resistant to Erythromycin and 68.2% of the isolates were resistant to Tetracycline. However all *E. coli* isolates tested in this study were susceptible to Imipenem. *Pseudomonas aeruginosa* isolates showed high percentage (100%) resistance to Tetracycline, Amoxicillin/Clavulanate and Trimethroprim /Sulphamethoxzole. Though, this bacterial isolates were less resistant to Ciprofloxacin with 3.3%. The sensitivity patterns were somewhat different for this isolated when compared to other studies, were results showed *E. coli* exhibited lower resistance of 19% to Trimethoprim/sulfamethoxazole and zero resistance to Amikacin and carbapenems (Călina *et al.* 2017).

Conclusion/Recommendations

In conclusion antimicrobial sensitivity patterns vary amongst isolates. The resistance patterns show a fluctuation in number of resistant isolates over the years. The antimicrobial resistant patterns of many pathogens showed that more than 20% of all isolates were resistant to most antibiotics in all the years of the study with some isolates were seen multidrug resistant. The most commonly isolated pathogens were *S. aureus* and *E. coli* followed by *Klebsiella spp* and *P. aeruginosa*. On antimicrobial susceptibility testing, Imipenem was the most effective drug, followed by Amikacin, and Gentamicin for overall bacterial isolates. More than 50% of all isolates during the study period showed resistance to erythromycin. This study give us an idea about the current incidence of SSIs throughout the country and the most common pathogens associated with this infections. The increasing number of infections equally alter the increase in antimicrobial resistant pathogens. The active number of isolates resistant to antibiotics is alarming and shows the need for actions. Although it is understandable that surgical site infections cannot be completely eliminated, a reduction in the infection rate to a minimal level can have significant benefits, such as a reduction in morbidity and mortality as well as a decrease in the cost of health care to both patient and health facility.

Continuous surveillance is essential to maintain a clear representation of the progress of antibiotic sensitivity in pathogens as this can aid in the selection of proper treatment for infections, a reduction in antibiotic use must be targeted as this will help minimize the growth of antibiotic resistance. Further studies to look at the overuse and over prescription of antibiotics is key to understand the cause of growth in bacterial resistance. Firmer laws and fines should be in place for those that do not abide to the policy of restricted sale of antibiotics.

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Appendix

List of Abbreviations

BHIS: Belize Health Information System

CDC: Center of Disease Control and Prevention

HAI: Hospital Acquired Infections

MOH: Ministry of Health

MRSA: Methicillin Resistant *Staphylococcus aureus*

SSIs: Surgical Site infections

WHO: World Health Organization

Operational Definitions

Below are definitions used in selecting cases included in the study.

Surgical procedure refers to an operation where at least one incision is made through the skin or mucous membrane, or reoperation via an incision that was left open during a prior operative procedure and takes place in an operating room.

Surgical wound refers to a wound created when an incision is made with a scalpel or other sharp cutting device and then closed in the operating room by suture, staple, adhesive tape, or glue and resulting in close approximation to the skin edges.