Estimation of antimicrobial costs in cases of surgical site infection

Estimativa dos custos com antimicrobianos em casos de infecção de sítio cirúrgico

Estimación de los costes antimicrobianos en casos de infección del sitio quirúrgico

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ABSTRACT: Objective: To estimate the costs of antimicrobials in patients with surgical site infections (SSI). **Method:** This is a descriptive, cross-sectional study with retrospective documentary analysis conducted at a tertiary public hospital with seven surgical rooms, averaging 750 surgeries per month. The micro-costing method used was the average direct cost of antibiotics, excluding intraoperative prophylactic antibiotics. Hospital infection investigation records were analyzed, and the study included records of patients diagnosed with confirmed surgical site infections (n=79) in 2021. Clinical data and direct costs of antimicrobials were examined. **Results:** The infection rate in this study was 6.76%. The specialties with the highest representation were digestive system and urological surgeries. Vancomycin was the most used antimicrobial, resulting in a total expenditure of R$ 7,345.68. Tigecycline incurred the highest total cost, amounting to R$ 79,655.52. Antimicrobials used to treat the 79 confirmed cases of SSIs totaled R$ 211,790.21 in costs. **Conclusion:** The average cost of antimicrobials per patient with SSI, considering total hospitalization days, was R$ 2,680.88, a significant component of total treatment costs. It is recommended to include cost analysis in the planning of hospital infection protocols.
Keywords: Surgical wound infection. Antimicrobial stewardship. Hospital costs. Health care costing systems. Health care costs.

RESUMO: Objetivo: Estimar os custos com antimicrobianos em pacientes com infecções de sítio cirúrgico. **Método:** Trata-se de um estudo descritivo, transversal, com análise documental retrospectiva, realizado em um hospital público terciário, com sete salas cirúrgicas, onde se realizam em média 750 cirurgias mensais. O método de microcusteio utilizado foi o custo direto médio dos antibióticos, não sendo incluído antibiótico profilático no intraoperatório. Analisaram-se as fichas de investigação de infecção hospitalar e foram incluídas no estudo as fichas de pacientes que tiveram o diagnóstico de infecção de sítio cirúrgico confirmado (n=79) em 2021. Foram verificados os dados clínicos e apenas os custos diretos com os antimicrobianos. **Resultados:** A taxa dessas infecções neste estudo foi de 6,76%. As especialidades com maior representatividade foram cirurgias do aparelho digestivo e urológicas. O antimicrobiano mais utilizado foi a Vancomicina, resultando no gasto total de R$ 7.345,68. O medicamento que gerou maior custo total foi a Tigeciclina, que representou R$ 79.655,52. Os antimicrobianos utilizados para tratar dos 79 casos confirmados de ISCs totalizaram o custo de R$ 211.790,21. **Conclusão:** A média de custo com antimicrobiano por paciente com ISC, no total de dias internados, foi de R$ 2.680,88, valor considerado representativo no custo total do tratamento. Recomenda-se a inclusão de análise de custos no planejamento de protocolos de infecção hospitalar.
Palavras-chave: Infecção da ferida cirúrgica. Gestão de antimicrobianos. Custos hospitalares. Sistemas de custos em instituições de saúde. Custos de cuidados de saúde.

RESUMEN: Objetivo: Estimar los costos de los antimicrobianos en pacientes con infecciones del sitio quirúrgico (ISQ). **Método:** Este es un estudio descriptivo, transversal con análisis documental retrospectivo realizado en un hospital público terciario con siete salas quirúrgicas, con un promedio de 750 cirugías por mes. Se utilizó el método de microcosteo, calculando el costo directo promedio de los antibióticos, excluyendo los utilizados como profilaxis intraoperatoria. Se analizaron registros de investigación de infecciones hospitalarias, incluyendo pacientes diagnosticados con ISQ confirmadas (n=79) en 2021. Se examinaron datos clínicos y costos directos de los antimicrobianos. **Resultados:** La tasa de infección en este estudio fue del 6.76%. Las especialidades con mayor representación fueron cirugías del sistema digestivo y urológicas. El antimicrobiano más utilizado fue la vancomicina, con un gasto total de R$ 7,345.68. Tigeciclina tuvo el costo total más alto, alcanzando R$ 79,655.52. Los antimicrobianos utilizados para tratar los 79 casos confirmados de ISQ sumaron R$ 211,790.21 en costos. **Conclusión:** El costo promedio de los antimicrobianos por paciente con ISQ, considerando los días totales de hospitalización, fue de R$ 2,680.88, un componente significativo de los costos totales de tratamiento. Se recomienda incluir análisis de costos en la planificación de protocolos de infección hospitalaria.
Palabras clave: Infección de la herida quirúrgica. Programas de optimización del uso de los antimicrobianos. Costos de hospital. Sistemas de costos en instituciones de salud. Costos de la atención en salud.

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INTRODUCTION

Healthcare-associated infections (HAI) are defined as infections acquired following a healthcare procedure or during hospitalization. They are further categorized into surgical site infections (SSI), hospital-acquired pneumonias, including ventilator-associated pneumonia (VAP), catheter-associated urinary tract infections (UTI), and venous catheter-associated bloodstream infections (BSI)[1].

The Centers for Disease Control and Prevention (CDC) developed standardized surveillance criteria to define SSI, classifying them as either incisional or organ/space. Incisional SSI are further divided into superficial incisional SSI, which involve only the skin and subcutaneous tissue of the incision (superficial), and deep incisional SSI, which involve deeper tissues of the incision. Both types occur within 30 days after the operation.

Organ/site SSI involve any part of the anatomy, other than the incised body wall layers, that was opened or manipulated during an operation. These infections occur within 30 days after the operation if no implant is left in place, or within a year if an implant is present and the infection is related to the operation[2].

Surgeries are classified based on the potential for contamination of the surgical wound, considering the number of microorganisms present in the tissue to be operated on. According to this classification, surgery can be considered clean, potentially contaminated, contaminated, or infected. This classification is essential for determining appropriate infection prevention and control measures in the surgical environment[3].

Among healthcare-related infections, SSI are the second most common in European and North American countries and the third most common in Brazil, occurring in 14 to 16% of all surgeries performed. These infections impact morbidity rates, prolong hospitalizations, increase costs and medication use, worsen patients' quality of life, and can lead to death[3].

For patients who develop SSI, the length of hospital stay increases by an average of four to seven days. These patients are twice as likely to require intensive care and have a fivefold increase in the likelihood of being readmitted after discharge. Additionally, healthcare costs for these patients rise substantially[4]. A study conducted in the United States shows that 5 to 10% of patients develop HAI, with the estimated average cost being US$25,000 per infected patient[5].

The unavailability, inconsistencies, or inaccuracies of cost information weaken its use in management practice and undermine the basis for maintaining the necessary economic-financial balance of hospitals[6].

Effective antimicrobial management, from prescription monitoring to distribution and administration, has proven to increase adherence to surgical antibiotic prophylaxis protocols, reduce the rate of SSI, and consequently lower antimicrobial costs[7].

Understanding the epidemiological profile of SSI and the costs of antimicrobials can help determine how much these infections contribute to the average cost of hospitalization for treating affected patients.

OBJECTIVE

Due to the critical importance of hospital cost management and its impact on overall management, this study aimed to estimate the costs associated with antimicrobial use in patients with surgical site infections.

MÉTODO

This descriptive, cross-sectional study employed retrospective documentary analysis with a quantitative approach. Cross-sectional studies aim to describe a situation or phenomenon at an unspecified time, offering advantages such as speed, simplicity, lower cost, and ease of obtaining a representative sample of the population[8]. The microcosting method used in this study calculates the average direct cost of antibiotics across all forms of presentation (oral, intravenous, solution, etc.), accounting for dosage variations. Antibiotics administered for intraoperative prophylaxis were excluded, with costs estimated after confirming the diagnosis of SSI during the Hospital Infection Control Commission (HICC) investigation.

Research scenario

The study was conducted at a tertiary public hospital situated in the northern region of Paraná, Brazil. This hospital is integral to the municipality's urgent and emergency care network and features a surgical center equipped with seven operating rooms, where an average of 750 surgeries are performed monthly. It serves as a referral center for trauma cases, high-risk pregnancies, and includes specialized units for burn treatment and bone marrow transplants, among other services.

Study population and sample

The sample was comprised of HAI investigation forms provided by HICC. After identifying patients who underwent surgery and developed SSI, which were confirmed and reported according to CDC criteria, the hospital information systems were used to retrieve data on antimicrobial consumption and the direct costs of antibiotics in the year 2021.

The inclusion criteria encompassed confirmed and reported cases of SSI in adults, regardless of specialty and type of surgery. Cases of other HAI were excluded.

Data collection procedure

In the first stage, HICC investigation and notification forms were analyzed. From these forms, information was extracted including the medical record and service number, patient age, date of admission and SSI symptoms, cultures performed, site of infection, surgical specialty, surgery performed, medications used, antimicrobials in use, and the outcome of care.

In the second stage, a spreadsheet was created containing the records of patients included in the study (n=79), specifically those who had SSI in 2021. The spreadsheet did not include patient names but rather the service numbers. This spreadsheet was forwarded to the hospital pharmacy, which provided data on the antimicrobials used, including dosage, therapeutic regimen, unit cost, and total cost of treatment.

In the third stage, data triangulation was performed, and a spreadsheet with consolidated data was created, generating a database for statistical analysis. The dependent variable was the patient with an SSI, while the independent variable was the antimicrobial in use with its respective cost (R$). Costs were measured from the manager's perspective — only direct costs of antimicrobials from the hospital billing system in 2023. The calculations were based on the values from the bidding minutes of the hospital pharmacy's most recent purchase, without monetary correction for the period.

Statistical analysis

Once the tabulation was completed, the collected data were subjected to descriptive and inferential analyses. The data were presented in both absolute and relative terms, and the analyses were performed using SPSS software (version 23) in conjunction with the features of Excel (version 2019).

Ethical aspects

The research was approved by the ethics committee and is linked to the project "Epidemiology of Surgical Site Infections in a University Hospital in Southern Brazil" under the number CAAE 03477018.2.0000.5231.

RESULTS

In 2021, a total of 5,572 clean surgeries were performed at the study hospital, of which 79 met the criteria for SSI. Table 1 shows the quarterly distribution of reported cases.

A similar monthly distribution was found, with a significant increase in the months of September and December. The SSI rate at the study hospital was 6.76%. In March, the highest number of healthcare-related infections was observed (133 in 297 surgeries). Regarding surgical site infections, the highest incidence was recorded in September (21 cases in 556 surgeries). Notably, out of the 5,572 clean surgeries performed in 2021 at this tertiary hospital in Paraná, HAI represented 20.93% (1,167 cases), and SSI accounted for 6.76% (79 cases), as shown in Table 2.

The surgical specialty with the highest number of SSI cases was the digestive system, with 19 cases. The majority

Table 1. Distribution of the number of clean surgeries and the number and percentage of healthcare-associated infections and surgical site infections. Londrina (PR), Brazil, 2023.

Month	Clean surgeries	HAI n (%)	SSI n (%)
January	349	60 (17.1)	3 (0.85)
February	349	72 (20.6)	3 (0.85)
March	297	133 (44.7)	5 (1.68)
April	374	95 (25.4)	1 (0.26)
May	425	110 (25.8)	1 (0.23)
June	406	114 (28.0)	1 (0.24
July	552	102 (18.4)	7 (1.26)
August	608	116 (19.0)	6 (0.98)
September	556	110 (19.7)	21 (3.77)
October	555	85 (15.3)	6 (1.08)
November	547	71 (12.9)	8 (1.46)
December	554	99 (17.8)	17 (3.06)
Total	5,572 (100%)	1,167 (20.93%)	79 (6.76%)

Source: the author.
HAI: health-associated infections; SSI: surgical site infections.

Table 2. Distribution of surgical site infection cases (%) by specialty, sex, age group, and number of deaths. Londrina (PR), Brazil, 2023.

Specialty	NSUR n (%)	DSS n (%)	URO n (%)	ORT n (%)	VC n (%)	HNS n (%)	OBST n (%)	THOR n (%)	CARD n (%)
SSI	8	19	12	9	13	3	8	2	5
Gender									
Female	50 (4)	42.1 (8)	33.3 (4)	22.2 (2)	46.1 (6)	—	100 (8)	—	20 (1)
Male	50 (4)	57.8 (11)	66.6 (8)	77.7 (7)	53.8 (7)	100 (3)	—	100 (2)	80 (4)
Age range (years)									
0 to 11	—	—	—	11.1 (1)	—	—	—	—	—
12 to 19	—	—	—	—	—	—	12.5 (1)	—	—
20 to 39	25 (2)	26.3 (5)	33.3 (4)	55.5 (5)	15.3 (2)	—	75 (6)	—	—
40 to 59	50 (4)	42.1 (8)	8.3 (1)	11.1 (1)	38.4 (5)	—	12.5 (1)	50 (1)	20 (1)
≥60	25 (2)	31.5 (6)	58.3 (7)	22.2 (2)	46.1 (6)	100 (3)	—	50 (1)	80 (4)
Number of deaths	25 (2)	21 (4)	41.6 (5)	22.2 (2)	15.3 (2)	—	12.5 (1)	50 (1)	40 (2)

Source: the author.

NSUR: neurosurgery, DSS: digestive system surgery; URO: urology, ORT: orthopedics; VC: vascular surgery; HNS: head and neck surgery; OBST: obstetrics; THOR: thoracic surgery; CARD: cardiac surgery.

of patients with SSI were male, accounting for approximately 57.8% of the cases. The age range most affected by SSI in this hospital unit was 40 to 59 years old, representing around 40% of the cases.

Regarding the number of deaths, the majority occurred in surgeries performed at the urology clinic, with a total of 5 deaths out of the 12 SSI cases recorded in this clinic.

The clinic with the lowest incidence of SSI was thoracic surgery, recording only two confirmed cases, both in male patients aged between 40 to 59 years old and over 60 years old. Out of these incidents, one resulted in death, representing a mortality rate of 50%.

The treatment of patients with SSI primarily involves medication, specifically antimicrobials. The drugs used in these patients in 2021, the focus of this study, are detailed in Table 3.

It appears that the most used antimicrobial was Vancomycin in the 500 mg presentation (1,524 units dispensed), at a unit cost of R$ 4.82, resulting in a total expenditure of R$ 7,345.68. The medication that incurred the highest total cost was Tigecycline in the 50 mg presentation, with a unit cost of R$ 169.12. A total of 471 units were dispensed, amounting to R$ 79,655.52.

To detail the direct cost involved in treating patients with SSI, a survey revealed a total cost of antimicrobials amounting to R$ 211,790.21. The average cost per patient was R$ 2,680.88, with a standard deviation of R$ 5,587.80. The distribution of values around the mean shows relatively low dispersion. The median cost per patient with SSI was R$ 1,041.71, indicating that half of the patients had costs below this value and half had costs above it.

DISCUSSION

Identification of a surgical site infection involves interpreting clinical and laboratory findings. It is crucial that a surveillance program uses consistent and standardized definitions; otherwise, rates of SSI may be calculated and reported inaccurately or in a manner that is difficult to interpret.

The results of this investigation revealed that patients undergoing surgery within the digestive system specialty experienced the highest incidence of SSI, likely due to this specialty conducting the highest number of surgical procedures at the study hospital. These findings align with a study published in 2020, which highlighted significantly high rates of SSI among patients undergoing digestive system surgery in underdeveloped countries. According to the study, out of 964 patients included, 114 developed SSI, resulting in an incidence of 11.8%. The authors attributed this high incidence to the natural colonization characteristics of the surgical site[9].

The acceptable rate of surgical site infections in hospitals can vary based on factors such as the type of surgical procedure, the patient population treated, the hospital environment, and the infection prevention and control measures implemented. However, according to recommendations in

Table 3. Antimicrobials used by patients who developed surgical site infection (n=79), according to unit cost, units used, and total cost in Brazilian Reais per medication. Londrina (PR), Brazil, 2023.

Antimicrobial	Unit cost (R$)	Units used	Total medication consumption in cases of SSI (R$)
Acyclovir 200 mg	0.19	72	13.68
Amikacin 500 mg	6.91	158	1,091.78
Amoxicillin + Potassium clavulanate 1.2 g	15.00	29	435.00
Ampicillin + Sulbactam sodium 3 g	9.94	256	2,544.64
Ampicillin 1 g	2.39	648	1,548.72
Azithromycin 500 mg	15.65	1	15.65
Cephalexin 500 mg	0.56	40	22.40
Cefalotin 1 g	5.09	222	1,129.98
Cefazolin 1 g	3.71	12	44.52
Cefepime 1 g	15.11	15	226.65
Cefeprime 2 g	17.99	45	809.55
Ceftazidime+ Avibactan 2.5 g	614.64	63	38,722.32
Ceftriaxone 1 g	4.97	108	536.76
Cefuroxime 750 mg	21.38	14	299.32
Ciprofloxacin 200 mg	16.84	707	11,905.88
Ciprofloxacin 500 mg	0.23	33	7.59
Clindamycin 300 mg	1.12	126	141.12
Clindamycin 600 mg	3.49	198	691.02
Colistimethate	13.01	16	208.16
Colistin 150 mg	59.88	60	3,592.80
Ertapenem 1 g	269.29	44	11,848.76
Fluconazole 200 mg	10.91	27	294.57
Gentamicin 40 mg	1.16	21	24.36
Gentamicin 80 mg	1.52	384	583.68
Imipenem + Cilastatin sodium 500 mg	19.38	4	77.52
Levofloxacin 500 mg	13.77	2	27.54
Linezolid 600 mg	25.57	111	2,838.27
Meropenem 1 g	20.44	844	17,251.36
Meropenem 500 mg	13.30	36	478.80
Metronidazole 250 mg	0.13	98	12.74
Metronidazole 500 mg	5.86	357	2,092.02
Micafungin 100 mg	327.65	16	5,242.40
Nitrofurantoin 100 mg	0.29	12	3.48
Oxacillin 500 mg	1.56	678	1,057.68
Piperacillin + Sodium tazobactam 4.5 g	16.27	555	9,029.85
Polymyxin B 500,000	25.00	381	9,525.00
Rifampicin 300 mg	2.34	32	74.88
Sulfamethoxazole + Trimethoprim 480 mg	0.19	24	4.56
Sulfamethoxazole + Trimethoprim 960 mg	Donation	51	0
Teicoplanin 400 mg	41.75	8	334.00
Tigecycline 50 mg	169.12	471	79,655.52
Vancomycin 500 mg	4.82	1524	7,345.68
Mean per patient n=79	—	395.48	2,680.88
Median	—	55.5	1,041.71
Standard deviation (SD)	—	304.70	5,587.80
Interquartile range	—	105	2,793.75
Total	—	8,503	211,790.21

Source: The author.
Caption: Unit was a generic term used to refer to pills, vials, and/or ampoules used in the treatment of surgical site infections (SSI).
SSI: Surgical Site Infections.

the Surgical Site Infection Prevention Manual, this rate should ideally remain between 2 and 5%[10-12].

It was evident that with an increase in the number of surgeries in the second half of 2021, SSI also increased. There is strong evidence that the use of prophylactic antibiotics, smoking cessation before any elective surgery, maintaining normothermia, and using chlorhexidine-based skin preparation are effective measures for controlling the occurrence of these infections and improving infection control levels[11].

Regarding the costs associated with the use of antibiotics, the average cost per patient is notably high. These costs can exert a significant impact on the healthcare system by increasing healthcare spending, potentially reducing the quality of care, diminishing the efficiency of healthcare delivery, and ultimately, negatively affecting public health[12].

Determining an accurate value for a patient's treatment is challenging due to numerous influencing factors such as the type of care, hospital, city, and region. According to the Institute for Supplementary Health Studies (*Instituto de Estudos de Saúde Suplementar* – IESS), the average cost of a hospital stay in Brazil is approximately R$ 8,000, considering patients across all medical specialties. This cost can vary based on factors like case complexity, length of hospitalization, need for exams, and procedures, among others. However, patients with HAIs often incur higher costs due to prolonged treatment, use of expensive medications, and additional procedures required to manage the infection. Studies indicate that the average cost of treating a patient with a hospital infection can be up to three times higher than that of a patient without such an infection[12].

SSI are among the most frequent postoperative complications, exerting significant impacts on patients' health. They contribute to prolonged hospital stays, increased morbidity and mortality rates, and heightened hospital costs. Furthermore, SSI can compromise patients' quality of life following hospital discharge, leading to pain, discomfort, and reduced functional capacity[13].

A limitation of this study is that the computerized hospital cost system does not facilitate direct comparison of costs between patients with and without SSI. While data on average cost per patient/day is available and can be stratified by billed hospital expenses, which falls outside the scope of the current study.

The advancement of knowledge from this study highlights the significant cost of antimicrobials in treating patients with SSI at a university hospital in northern Paraná. This insight enables managers to conduct similar analyses, potentially reducing the incidence of SSI and associated costs through targeted infection control measures.

CONCLUSIONS

In this study, the rate of SSI was 6.76% out of 5,572 clean surgeries performed in 2021. The clinics with the highest representation of SSI were digestive system, urological, and vascular surgeries. The most frequently used antimicrobial was Vancomycin in the 500 mg presentation, with 1,524 units dispensed at a unit cost of R$ 4.82, resulting in a total expenditure of R$ 7,345.68. The medication that incurred the highest total cost was Tigecycline in the 50 mg presentation, with a unit cost of R$ 169.12. A total of 471 units were dispensed, amounting to R$ 79,655.52. Micafungin 100 mg had the highest cost per unit dose (R$ 327.65), with sixteen units dispensed, resulting in an expense of R$ 5,242.40.

The antimicrobials used to treat the 79 confirmed cases of SSI resulted in a total cost of R$ 211,790.21. The average cost of antimicrobials per patient with SSI was R$ 2,680.88.

Furthermore, nurses play a crucial role in educating and guiding the nursing team. They are responsible for preparing and administering antimicrobials and implementing preventive measures, applying techniques and protocols. Doctors also have a central role in diagnosing, prescribing, and treating SSI. They oversee the monitoring of cultures and the progression of SSI, collaborating with pharmacists to evaluate the best cost-benefit approach for treatment.

In conclusion, it is crucial to work within a multidisciplinary team for the prevention and control of SSI. This collaborative approach significantly enhances the safety of surgical patients and reduces costs associated with treating HAI, implementing protocols that incorporate cost-benefit analyses.

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CONFLICT OF INTERESTS

The authors declare there is no conflict of interests.

AUTHORS' CONTRIBUTIONS

DNGN: Project administration, Conceptualization, Methodology, Writing – review & editing, Visualization. EFC: Data curation, Investigation, Writing – original draft, Validation. CCTF: Formal analysis, Methodology, Writing – review & editing, Supervision. IFLF: Investigation, Writing – review & editing, Visualization. MCP: Investigation, Writing – review & editing, Visualization. KMB: Conceptualization, Investigation, Methodology, Supervision.

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