

# *Klebsiella pneumoniae* producing carbapenemase-KPC outbreak in a neonatal unit - a case-control study for risk factors

*Surto de Klebsiella produtora de carbapenemase KPC em Unidade Neonatal - estudo de caso-controle sobre fatores de risco*

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## ABSTRACT

**Aim:** *Klebsiella pneumoniae* producing carbapenemase KPC (Kp-KPC) has emerged and spread globally as a significant cause of Healthcare-Associated Infections (HAI) and outbreaks. The purpose of this study was to describe HAI and an outbreak and identify risk factors associated with infections/colonization caused by KPC in a Neonatal Unit. **Methods:** This case-control study was conducted in a referral Neonatal Unit between December/2022 and June/2023. Newborns infected and/or colonized by Kp-KPC were considered cases, and the control group was matched by weight range and admission date. Clinical and data results of the two groups were compared to identify risk factors. Database was analyzed by SPSS v21.0. Study was approved by Ethical Committee. **Results:** A total of 121 newborns (28 cases of Kp-KPC colonization/infection and 28 controls) were followed up. Higher density of HAI was observed in the range of newborns with birth weight < 750g and 1,501 to 2,500g and, in those using invasive devices, specially associated with central venous catheter. Previous surgical procedure was the main variable associated with the presence of Kp-KPC. **Conclusions:** The neonatal population is at high risk for HAI. Preventive measures involving invasive procedures of newborns are extremely important for assistance of these population.

**Keywords:** *Klebsiella pneumoniae*; Carbapenem-resistant enterobacteriaceae; Newborn; Outbreak.

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## RESUMO

**Objetivo:** A *Klebsiella pneumoniae* produtora de carbapenemase KPC (Kp-KPC) surgiu e se espalhou globalmente como uma causa significativa de Infecções Relacionadas à Assistência à Saúde (IRAS) e surtos. O objetivo deste estudo foi descrever IRAS e um surto e identificar fatores de risco associados a infecções/colonização causadas por KPC em uma Unidade Neonatal. **Métodos:** Este estudo de caso-controle foi conduzido em uma Unidade Neonatal de referência entre dezembro/2022 e junho/2023. Recém-nascidos infectados e/ou colonizados por Kp-KPC foram considerados casos, e o grupo-controle foi pareado por faixa de peso e data de admissão. Os resultados clínicos e de dados dos dois grupos foram comparados para identificar fatores de risco. O banco de dados foi analisado pelo SPSS v21.0. O estudo foi aprovado pelo Comitê de Ética. **Resultados:** Um total de 121 recém-nascidos (28 casos de colonização/infecção por Kp-KPC e 28 controles) foram acompanhados. Maior densidade de IRAS foi observada na faixa de recém-nascidos com peso de nascimento < 750g e 1.501 a 2.500g e, naqueles em uso de dispositivos invasivos, especialmente associados ao cateter venoso central. Procedimento cirúrgico prévio foi a principal variável associada à presença de Kp-KPC. **Conclusões:** A população neonatal apresenta alto risco para IRAS. Medidas preventivas envolvendo procedimentos invasivos em recém-nascidos são de extrema importância para assistência a essa população.

**Palavras-chave:** *Klebsiella pneumoniae*; Enterobacteriaceas resistentes a carbapenêmicos; Recém-nascido; Surto.

## Conflicts of Interests:

None.

## Ethic Committee:

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## INTRODUCTION

The *Klebsiella pneumoniae* producing carbapenemase-KPC (Kp-KPC) has emerged and spread globally as a significant cause of Healthcare-Associated Infections (HAIs) and outbreaks, highlighting its epidemiological importance in neonatal intensive care units (NICUs). Transmission can occur from mother to child at birth, or acquired in units, by person-to-person transmission, by cross-transmission through the hands of care staff, equipment, diet or contaminated environment<sup>1-3</sup>. In addition, it is described that intestinal colonization of newborns may maintain a carrier state<sup>4</sup>.

Among the mechanisms of resistance to carbapenems, the production of enzymes that hydrolyze beta-lactams (including penicillins, cephalosporins, cephamycins, monobactams, and carbapenems) has a significant impact due to their hydrolytic efficiency, the coding of genes in genetic elements such as plasmids and transposons, and rapid dissemination<sup>5</sup>. Genetic studies have also been carried out to identify the presence of resistance genes in *Klebsiella*

*pneumoniae* strains responsible for colonization in the neonatal population<sup>3,6,7</sup>.

These bacteria may have the capacity to cause life-threatening infections in newborns, including neonatal sepsis with a focus on the meningeal, urinary, pulmonary and soft tissue<sup>8</sup>. Rates of morbidity and mortality rates are high due to limited antibiotic options, as these microorganisms demonstrate resistance to carbapenems and other antimicrobials, and are included in the Carbapenem-Resistant Enterobacteriaceae (CRE) group<sup>5</sup>.

An increasing rate of colonization and infections due to carbapenem-resistant *Klebsiella* sp. in neonates has been documented in recent years<sup>1,9,10</sup>. Given the increase in outbreaks associated with this microorganism, it has become crucial to identify the elements that increase the risk of colonization and infection in order to implement effective preventive measures. In Neonatal Units, this is an even greater concern, when considering the low innate and adaptive immune response of this population<sup>11</sup>.

In studies that evaluated colonization and/or infection by resistant Gram-negative microorganisms in newborns, lower weight, prematurity, invasive procedures and devices (MV, CVC, SVD), previous use of antimicrobials, parenteral nutrition, and length of hospitalization were identified as associated factors<sup>12-23</sup>.

Therefore, in this study, an outbreak was investigated and described to identify risk factors associated with infection/colonization caused by Kp-KPC in a referral Neonatal Unit.

## METHODS

This is a cohort with a nested case-control study carried out from December 2022 to June 2023, at the Neonatal Unity of the Hospital das Clínicas of UFMG (HC/UFMG), which includes the Neonatal Intensive Care Unit (NICU), the Neonatal Intermediate Care Unit (UCINCo), and the Kangaroo Neonatal Intermediate Care Unit (UCINCa).

All newborns admitted to the Neonatal Care Unit were included for cohort follow-up, according to the Infection Control Surveillance recommendations. The inclusion criteria for the nested case-control study were as follows: a) cases – patients infected and/or colonized by *Klebsiella pneumoniae* Carbapenemase Producing KPC (KPC); b) control group – newborns with negative surveillance cultures, matched by birth weight range and by date of hospitalization within one month of the case's admission date.

Patients who did not stay for at least 24 hours, as well as those who lacked the necessary information for analysis, were excluded.

Data collection was carried out prospectively and systematically, daily, by a specialized and trained professional from the Hospital Infection Control Committee of HC/UFMG. This was done in accordance with the National Health Surveillance Agency (ANVISA) guidelines surveillance of infection in critical units<sup>24,25</sup>. The criteria for reported infections followed the definitions for ANVISA Neonatal Units<sup>26</sup>.

The predictive variables evaluated as risk factors for case-control study were: use and duration of invasive devices (Central Venous Catheter - CVC; Mechanical Ventilation - MV; Indwelling Urinary Catheter - IUC), surgery, parenteral nutrition, use and duration of antimicrobials, and length of stay at the Neonatal Unit. All predictive variables were included prior to the occurrence of colonization or infection.

Cultures were performed according to the routine procedures in the microbiology laboratory. The identification of microorganisms was performed using an automated phenotypic method (bioMérieux VITEK<sup>®</sup> 2 system). Antimicrobial susceptibility tests were performed according to the protocol of the Brazilian Committee on Antimicrobial Susceptibility Testing – BrCAST<sup>5</sup>, using disk

diffusion, automated minimum inhibitory concentration (VITEK<sup>®</sup> 2 system), and concentration gradient (E-test<sup>®</sup>, bioMérieux). Carbapenemase detection was performed using a lateral flow immunochromatographic method (NG-TEST CARBA<sup>®</sup> 5, Laborclin).

The outbreak definition of KPC was defined when the number of cases of infection OR colonization cases exceeded 3 standard deviations above of the endemic level, based on a Control Chart, since this microorganism was not prevalent at the Neonatal Unity. The average incidence level was 0.2 cases. The alert level was defined as one case (2SD), and the control level was defined as 1.5 cases per 1,000 patient-days. Then, a rectal swab was performed to identify other colonized patients and define mitigation measures.

The collected data were entered into an internal program, later compiled into an Excel<sup>®</sup> file and imported into the Statistical Package for Social Sciences (SPSS) v21.0 for statistical analysis. The analysis included the frequency of patients and the median (with range) of weight and its distribution by weight category; number of patient-days; frequency of Healthcare-Associated Infections (HAIs) by topography and microorganisms isolated in HAIs; incidence density of HAIs per 1,000 patient-days; incidence density of invasive device infections; frequency of HAIs associated with death and lethality rate; frequency of predictive categorical variables; and the mean and standard variation of continuous variables compared between patients in the case and control groups, including gender, previous surgery procedure, central venous catheter (CVC), mechanical ventilation (MV), indwelling urinary catheter (IUC), parenteral nutrition (PN), previous use of antimicrobial agents, and length of stay in Neonatal Unity.

The study is part of the mandatory actions of the Hospital Infection Control Committee, in accordance with national legislation<sup>24,25</sup>, and was approved by the institution's Ethics Committee (CAAE 589736.2.0000.5149).

## RESULTS

During the study period, 121 newborns were followed in the HC/UFMG Neonatal Unit. Considering the time at risk, there were 3,044 patient-days, with an HAI incidence density (ID) of 20 cases per 1,000 patient-days. A higher incidence density of HAIs was observed in the range of newborns (NB) with birth weight (BW) < 750g and 1,501 to 2,500g. The number of patients at risk, HAIs, incidence density of HAIs, HAIs associated with death, and lethality rate are shown in Table 1.

The highest density of device-associated HAIs was observed for laboratory-confirmed sepsis associated with CVC use, with 8.5 cases per 1,000 CVC-days, followed by IUC-associated urinary tract infection, with 4.6 per 1,000 IUC-days (Table 2).

**Table 1.** Patient at risk, HAIs, HAI incidence density, HAIs associated with death and lethality, Neonatal Unit of HC/UFGM, December 2022 to June 2023.

	Patient at risk	Patient-days	HAI*	HAI ID <sup>†</sup> (n/1000 patient-days)	HAIs associated with death	Lethality (%)
< 750 g	5	263	6	22.8	3	50
751 - 1000 g	5	240	3	12.5	0	0
1001 - 1500 g	16	591	6	10.2	1	16.7
1501 - 2500 g	43	1037	28	22.5	7	25
> 2500g	52	913	17	18.6	0	0
Total	<b>121</b>	<b>3044</b>	<b>60</b>	<b>19.7</b>	<b>11</b>	<b>18.3</b>

Legend: \* HAI = Healthcare-Associated Infection; <sup>†</sup> ID = Incidence density.

**Table 2.** Incidence density of HAIs associated with an invasive device, Neonatal Unit of HC/UFGM, December 2022 to June 2023.

	Cases (N)	Device-day	HAI* ID <sup>†</sup> (n/1000 device-days)	Duration (Median days)	Utilization rate (Device-day/Patient-day)
CVC <sup>‡</sup> -associated sepsis	12	1062	11.2	6	0.35
IUC <sup>§</sup>	1	217	4.6	4	0.07
MV <sup>¶</sup>	0	643	0	5	0.21

Legend: \* HAI = Healthcare-Associated Infection; <sup>†</sup> ID = Incidence density; <sup>‡</sup> CVC = Central Venous Catheter; <sup>§</sup> IUC = Indwelling Urinary Catheter; <sup>¶</sup> MV = Mechanical Ventilation.

The outbreak began with two cases of infection as urinary focus sepsis caused by KPC. The first case of a urinary source infection was identified in a surgical patient who underwent laparotomy. The infection was identified through culture isolation in a patient with IUC, CVC (PICC), and MV. The second case of infection with urinary focus occurred in a patient who did not have any invasive devices.

Thus, 2 cases of KPC infection were defined, and 26 cases of colonization were detected through rectal swab screening. A total of 28 of KPC colonization/infection were considered as cases, matched with 28 controls. The median weight was 1,844.5g, with a range of 610 to 4,025g, and the average length of stay until colonization/infection or discharge/death was 23.71 days (SD 28.46).

In a surveillance swab, two previous cases of colonization were identified within the month of case identification. Another case was identified later, in the same month of surveillance, in a patient who also underwent a surgical procedure. If we consider the first epidemiological weeks of surveillance, three patients of the first six cases with KPC isolation were patients who underwent a surgical procedure. Until the 18th epidemiological week of 2023, nine colonized/infected patients had undergoing surgical procedures.

There were 11 cases of deaths associated with HAIs, however, none of them were associated with

infection/colonization by KPC. Among patients with KPC colonization/infection, there were two deaths not associated with HAIs.

In the 28 cases of infection/colonization by KPC, *Klebsiella pneumoniae* was the identified specie. During the study period, 14 cases of infection by Gram-negative bacteria were identified, with four cases of *Enterobacter cloacae*, six cases of *Klebsiella* sp. (three cases of *Klebsiella pneumoniae*, two cases of *Klebsiella aerogenes*, one case of *Klebsiella oxytoca*), three cases of infection by *E. coli*; and one case by *Pseudomonas aeruginosa*. Two of the six cases of infection by *Klebsiella* sp. were KPC, identified in urine culture, confirmed by immunochromatographic method, and were included in the group of cases of the nested case-control study. Table 3 presents the Gram-negative microorganisms isolated in cases reported as infection, according to topography.

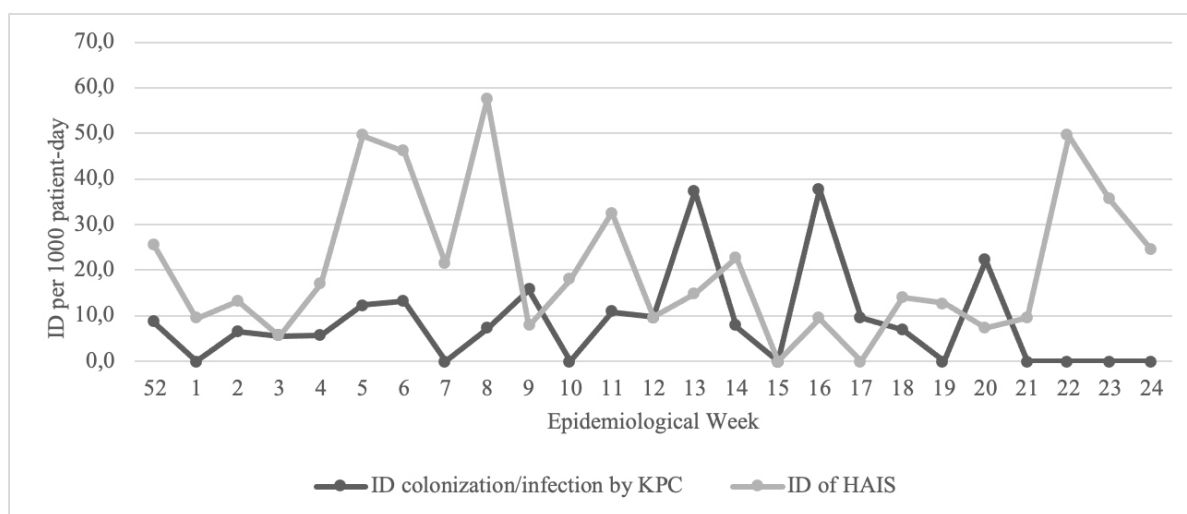
Figure 1 presents the Control Chart of the general incidence density of HAIs and colonization/infection by Kp-KPC throughout the study period.

Regarding the risk factors assessed, previous surgical procedure presented statistically significant difference between groups. Other variables analyzed did not demonstrate statistical significance in this study. The assessed risk factors are found in Table 4.

**Table 3.** Frequency of HAIs reported by topography and isolated microorganism, Neonatal Unit of HC/UFMG, December 2022 to June 2023.

Topography	Microorganism	N (%)
Conjunctivitis	- <i>Escherichia coli</i>	1 (7,14)
	- <i>Klebsiella oxytoca</i>	1 (7,14)
Necrotizing enterolitis	- <i>Enterobacter cloacae</i>	1 (7,14)
Soft tissue infection	- <i>Enterobacter cloacae</i>	1 (7,14)
	- <i>Klebsiella pneumoniae</i>	3 (21,4)*
Urinary tract infection	- <i>Enterobacter cloacae</i>	2 (14,3)
	- <i>Enterobacter aerogenes</i>	1 (7,14)
	- <i>Escherichia coli</i>	1 (7,14)
Laboratory confirmed early onset-sepsis	- <i>Escherichia coli</i>	1 (7,14)
Laboratory confirmed late onset-sepsis	- <i>Enterobacter aerogenes</i>	1 (7,14)
	- <i>Pseudomonas aeruginosa</i>	1 (7,14)
TOTAL	Gram-negative bacteria	14 (100)

\*Two cases of urinary tract infection by *Klebsiella pneumoniae* producing carbapenemase (Kp-KPC).



**Figure 1.** Incidence density (ID) of Healthcare-Associated Infection (HAIs) and colonization/infection by *Klebsiella pneumoniae* producing carbapenemase (KPC), Neonatal Unit of HC/UFMG, December 2022 to June 2023.

**Table 4.** Risk factors for the occurrence of Colonization/Infection by *Klebsiella pneumoniae* producing carbapenemase-KPC, Neonatal Unit of HC/UFMG, December 2022 to June 2023.

	Case	Control	p
<b>Gender N (%)</b>			
Male	8 (14.3)	8 (14.3)	1*
Female	20 (35.7)	20 (35.7)	
<b>Surgery N (%)</b>			
Yes	9 (16.1)	3 (5.4)	0.05†
No	19 (33.9)	25 (44.6)	
<b>CVC (N%)</b>			
Yes	16 (28.6)	17 (30.4)	0.78*
No	12 (21.4)	11 (19.6)	
<b>MV (N%)</b>			
Yes	16 (28.6)	15 (26.8)	0.79*
No	12 (21.4)	13 (23.2)	

<b>IUC (N%)</b>			
Yes	5 (8.9)	8 (14.3)	0.34*
No	23 (41.1)	20 (35.7)	
<b>PN (N%)</b>			
Yes	6 (10.7)	7 (12.5)	0.75*
No	22 (39.3)	21 (37.5)	
<b>Antibiotic (N%)</b>			
Yes	12 (21.4)	16 (28.6)	0.29*
No	16 (28.6)	12 (21.4)	
<b>CVC (mean/SD - days)</b>	11.14 (22.69)	7.46 (10.87)	0.44‡
<b>MV (median/range - days)</b>	2 (0 a 101)	1 (0 a 50)	0.25§
<b>IUC (mean/SD - days)</b>	0.79 (2.54)	2.07 (5.49)	0.27‡
<b>PN (mean/SD - days)</b>	2.04 (7.47)	3.75 (11.53)	0.51‡
<b>Antibiotic (mean/SD - days)</b>	6.68 (15.70)	4.64 (5.84)	0.52‡
<b>Length of stay#</b>	24.68 (33.78)	22.75 (22.52)	0.80‡

Legend: # Until colonization/infection or discharge/death; \* Chi-square; † Fisher test; ‡ T-test; § Mann-Whitney / CVC = Central Venous Catheter; MV = Mechanical Ventilation; IUC = Indwelling Urinary Catheter; PN = Parenteral Nutrition.

## DISCUSSION

The rates of resistant microorganisms, including KPC-producing bacteria<sup>6,27</sup>, have been increasing in Neonatal Units. Because of the limitations of studies in this population, identifying risk factors is important for establishing preventive measures given the high risk of mortality<sup>8</sup> and scarcity of therapeutic options<sup>5</sup>. It is noteworthy that a study carried out in a Neonatal Unit in China identified *Klebsiella* strains producing carbapenemase KPC that were also resistant to Cefazidime-Avibactam<sup>28</sup>.

The results of the present study demonstrated that the occurrence of previous surgical procedures is associated with colonization/infection by Kp-KPC in newborns admitted to the Neonatal Intensive Care Unit (NICU). Previous studies have also evaluated previous surgery as a risk factor for infections by resistant microorganisms<sup>8,10,14,15</sup>. The study by Akturk et al. (2016)<sup>10</sup> included neonatal and pediatric patients and found an association between surgical procedure and colonization by carbapenem-resistant *Klebsiella pneumoniae* in multivariate analysis. The study also demonstrated that previous use of carbapenem, underlying metabolic condition, and neutropenia were associated with colonization by the microorganism. In a case-control study conducted in a neonatal unit in Turkey, Bor et al. (2021)<sup>8</sup> identified that surgery was a predictor of mortality due to carbapenem-resistant *Klebsiella pneumoniae* infection in univariate analysis, and the presence of congenital malformations maintained a significant association in multivariate analysis, which represents the profile of the population that frequently requires surgical procedures, as in the present study. Cantey et al. (2013)<sup>15</sup> identified bedside surgical procedures, longer stay in the same unit, and time at risk (patient-day) as significant predictors of ESBL-Kp colonization/infection. The study by Ulu-Kilic et al. (2017)<sup>14</sup> evaluated risk factors for acquisition of resistant *Acinetobacter baumannii* in an outbreak in a neonatal unit and, although surgery was not identified as a risk factor

with statistical significance, the authors considered cross-transmission in the hospital due to the use of operating rooms and invasive procedures in common with adult patients where XDR-*Acinetobacter baumannii* is endemic. These authors also identified peritoneal dialysis, which may be associated with urinary tract malformations, as a procedure associated with the isolation of the microorganism, with the dialysis catheter being inserted in the Operating Room.

Other risk factors investigated did not demonstrate significant differences between the case and control groups in the present study, although risk factors for colonization and infection by resistant microorganisms, including resistant Gram-negatives, are established in the literature<sup>12-23</sup>. The literature also describes other variables associated with infection/colonization in Neonatal Units, such as ventilatory support, inhalation therapy, airway suction, use of oxygen, humidified incubator, tube feeding, and use of a ventilator unit. These were also described as predictors in studies evaluating outbreaks of multidrug-resistant *Klebsiella pneumoniae*, *Serratia marcescens*, and *Acinetobacter baumannii*<sup>15,29,30</sup>, highlighting the environment, material, and water as sources of cross-transmission<sup>31</sup>.

In a meta-analysis that included cited studies, the risk factors for colonization/infection by resistant microorganisms in the Neonatal Unit were use of venous access (OR 1.58; CI95% 1.14 – 2.20); mechanical ventilation (OR 7.55; CI95% 4.27 – 13.36); and parenteral nutrition (OR 4.79; CI95% 2.23 – 10.29)<sup>27</sup>.

The high frequency of Gram-negative bacterial isolates among the 14 reported cases of HAI is noteworthy, including seven cases of urinary tract infection, and two of these cases were due to Kp-KPC. This profile is predominantly described in neonatal sepsis in Neonatal Units of low- and middle-income countries, characterized by the presence of multidrug-resistant microorganisms<sup>32</sup>. In a review published by Johnson et al. (2017)<sup>33</sup>, a greater number of outbreaks of Gram-negative bacteria were observed, compared to

Gram-positive bacteria in several Neonatal Units in the period from 2015 to 2017. However, in this review, only Gram-negative outbreaks were observed in developing countries, while outbreaks of *S. aureus*, coagulase-negative *S.*, and *Enterococci* were reported in the USA, Japan, Czech Republic, Germany, France, Belgium, and Australia<sup>33</sup>.

The highest incidence density of device-associated infection was catheter-associated infection in the present study, similar to national data in all weight ranges<sup>34</sup>. However, when considering the largest number of Gram-negative infections reported were in the urinary tract, with two of them by Kp-KPC, it is noteworthy that the incidence density of UTI associated with SVD was similar to that of the previous study carried out in the same unit between 2009 and 2010, with a total of 609 patients and a rate of 5.2 per 1,000 SVD-day<sup>35</sup>. This incidence density is similar to the densities described in other middle- and high-income countries that ranged from 5.8 to 5.4/1,000 SVD-day before intervention to prevent device-related infection<sup>36</sup>. However, after interventions, this systematic review<sup>36</sup> shows a significant reduction in incidence density, with rates of up to 1.5 to 2.49, which reveals the need for intervention with this objective. It is noteworthy that urinary tract infection associated with SVD is uncommon in Neonatal Units, since indwelling urinary catheters are not widely used. With a low density of SVD-day, the observed number of infections impacts the density of infections associated with this device. It is worth noting that the study by Vergadi et al. (2017)<sup>37</sup> demonstrated that previous hospitalizations in Neonatal Intensive Care Units with an outbreak of KPC are associated with community-onset urinary tract infection, even in the absence of urinary tract anomalies, which generates new hospitalizations and higher healthcare costs.

The total incidence density of HAIs was higher when compared to that of developed countries and similar to or lower than that of low-income countries<sup>38-41</sup>. When considering data stratified by continent, the incidence density in the present study was higher than that described in countries in Southern Latin America, which includes states of Brazil itself<sup>39</sup>. The density of HAIs was also higher when compared to national data<sup>34</sup> and to data from the State of São Paulo<sup>42</sup>. However, this rate was lower than in previous studies conducted from 2008 to 2009<sup>42</sup> and 2009 to 2010<sup>43</sup> in the same Neonatal Unit, with HAI DI of 22.8 and 26.3 per 1,000 patient-days, respectively. The group of newborns with a birth weight of less than 750 g had the highest incidence density of HAIs, as described in the international literature<sup>38,44-45</sup>, and was similar to that found in previous studies in the same unit of the present study<sup>43,46</sup>. A high density of HAIs was also observed in neonates weighing between 1,500 g and 2,500 g, as well as those weighing more than 2,500 g. The higher density of HAIs in these weight ranges is due to the fact that the maternity hospital is a reference for high-risk pregnancies. It has a Neonatal Unit treats complex cases and cares for high-risk newborns, especially patients with malformations<sup>47,48</sup>. These patients require invasive surgical procedures and prolonged devices such as CVC and SVD, in addition to prolonged hospital stays, with a higher risk of HAIs.

Regarding the control chart, an increase in the incidence density of HAIs was observed in epidemiological week 22. This rise can be explained by the limitation of admission of newborns to perform terminal disinfection in the Unit as a recommended outbreak mitigation measure<sup>49</sup>, which resulted in a reduction in the denominator, with a lower number of patients in the Neonatal Unit during the period.

The limitations of the present study include an uneven distribution of patients, with a predominance of those weighing more than 1500g, presenting malformations, and requiring surgical procedures, which may affect the generalization of the findings to the general population. In addition, cross-transmission of microorganisms throughout the period after the surgical procedure may have influenced the persistence of the microorganism in the Neonatal Unit and influenced the variables associated with the outcome. The lack of association of other predictor variables in this study may be attributed to the sample size and the prolonged outbreak period, which favors cross-transmission, which was highlighted in studies described in Neonatal Units<sup>14,15</sup>.

It is also worth noting that high-risk newborns, such as surgical patients, require frequent handling of devices. Recommendations for safe surgery must be monitored as practices to prevent cross-transmission<sup>50</sup>.

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## CONCLUSION

In conclusion, surgical procedures have been associated with infection/colonization by Kp-KPC. Established safety practices for the preoperative, intraoperative, and postoperative stages, such as prophylactic antimicrobials one hour before the procedure, adequate sterilization process, skin and hand antisepsis, proper surgical attire for the team, and continued training in prevention and control measures, are essential as preventive measures.

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## AUTHOR'S CONTRIBUTION

We describe contributions to the papers using the taxonomy (CRediT) provided above:

*Oversaw and led the planning, administration, and execution of the project, participated in data curation and formal analysis, supervised the investigation and designed the methodology, assisted with material forecasting, collaborated on the statistical analysis and validation of the study, and participated in the writing and review of the manuscript:* LM Anchieta; RMC Romanelli. *Participated in the conceptualization, data collection and curation, and statistical analysis:* BHM Tarabai; *Participated in the collection, curation, and analysis, and in the writing and review of the manuscript:* JHP Rodrigues; JP Fontis; JPR Viana; *Assisted in the conceptualization and design of the methodology, performed resource forecasting and statistical analysis, and participated in the writing and review of the manuscript:* GA Armond; PHO Mourão; MLBB Souza.

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