Original article

Attributable costs and risk factors for nosocomial infection in a pediatric Hospital of Sonora, Mexico: 2008

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Abstract

Background. Hospital acquired-infections (HAI) generate substantial financial burden to the budget of medical institutions, mainly due to the additional costs derived from risk factors associated with medical procedures.

Methods. A cross-sectional study was carried out in the Hospital Infantil del Estado de Sonora from October 2007- January 2008. Multivariate logistic regression was performed to estimate the risk of HAI. Economic burden was assessed through a partial analysis of costs.

Results. We found that length of hospital stay [OR = 34.1, 95% CI (5.2-59.9)], device utilization [central venous catheter (OR = 7.5, 95% CI (2.2-12.4)], and peripheral catheter [OR = 10.2, 95% CI (3.3-17.7)] were associated with the development of HAI. The total economic cost of 51 HAI episodes was $110, 950 USD, whereas the average cost/episode was $2079.80 USD.

Conclusion. Economic costs attributable to HAI caused an excess of 56% in overall costs of hospitalized patients. Strategies to reduce the length of hospital stay as well as to improve catheter manipulation can contribute to reduce the risk of HAI and to avoid the excessive cost generated by its occurrence.

Key words: hospital-acquired infections, cost analysis, pediatrics, Sonora.

Introduction

Hospital-acquired infections (HAI) represent a serious public health problem with a high clinical and epidemiological impact because they increase morbidity and mortality rates as well as the length of hospital-stay and its associated health care costs.[1,2]

There are several problems related with HAI beyond the clinical setting. One of the major problems is the financial burden produced by HAI. Several studies reveal there is an excessive cost that impacts institutional budgets.[3-6] No hospital service is exempt from experiencing a financial burden as a result of HAI; however, control programs may reduce its deleterious impact, especially if they are targeted towards key risk factors causing HAI.[7]

In Mexico, the average cost associated with HAI has been estimated to be $5350 USD.[7] In 2003, 28,500 HAI cases were recorded through the Hospital Epidemiological Surveillance Network (which includes 133/1005 public hospitals). This represented in 2003 an annual expense associated with HAI of 152,480,544.74 USD. This figure is >6% of the

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total budget assigned to the Secretary of Health in 2004. It has been estimated that controls recommended in the Mexican Official Norm (NOM-EM-002-SSA2.2003) could prevent ~9400 HAI cases and reduce associated health care costs by $50,318,579.76 USD.[8]

Financial assessment of HAI represents a research strategy that helps identify associated costs as well as consequences in the health of hospitalized patients. This assessment is a clinical and administrative tool to control HAI that every hospital should implement. These tasks require the identification of key risk factors associated with HAI to design strategies with better cost/benefit results.

Because of the aforementioned, we carried out an exploratory study to evaluate risk factors related with HAI incidence and also to estimate direct economic costs associated without correlating them. Therefore, we conducted a study in clinical services for internal medicine, infectology and pediatric intensive care unit (PICU) in the Hospital Infantil del Estado de Sonora (HIES).

Patients and methods

We carried out a cross-sectional study between October 1, 2007 and January 31, 2008 approved by the ethics committee of our hospital. HIES is the largest pediatric hospital in the state of Sonora (Mexico) with 122 beds. The hospital covers the health needs of the population between 0 and 18 years of age who are not covered by the Mexican health care system. We selected patients from the following services to include in our study: ICU (six beds), infectology (30 beds), and internal medicine (17 beds).

Nonprobability sampling was used to include patients between 1 month and 18 years who had been hospitalized for at least 48 h in selected services and were diagnosed with HAI. We used criteria from the Mexican Official Norm for epidemiologic surveillance, prevention and control of nosocomial infections (NOM 045-SSA2-2005). These criteria regard HAI as a localized/generalized condition resulting from an adverse reaction to an infectious agent (or its toxin) that was not present or incubating when the patient was admitted to the hospital. We included only the first HAI episode from each patient. Patients were selected through intentional evaluation by a trained physician and a nurse, reviewing secondary data sources such as admission reports, nursing notebooks and reports of suspicious cases from resident physicians. The responsible relative or guardian of selected patients signed informed consent in order to participate in the study.

We excluded all patients with infection not acquired at the study site and not developed within the hospitalization period or acquired in other clinical services than those selected in the study. We excluded subjects without complete clinical file or without HAI report.

The final population included 51 HAI cases and 141 controls. All cases were matched with controls who attended the same clinical service and had no confirmed or suspected HAI diagnosis. Controls were matched by admission date, age and gender. Controls were patients admitted for a reason different than HAI and presented an appropriate evolution on their admission pathology.

A trained physician gathered data through a structured, closed questionnaire to explore the following variables: age, gender, diagnosis at admission, total hospitalization days, prolonged stay [>3.9 days, average hospital stay plus standard deviation (3.1)], surgical procedures, catheter usage (pleural, nasogastric, Foley), history and dates for tracheotomy, gastrostomy, parenteral nutrition, central venous catheter (CVC), venous dissection or venous punctures, cultures and their dates (blood, urine, feces, cerebrospinal fluid), antibiotics and length of treatment and patient's final condition. Specific items were added to estimate costs of medical procedures associated with HAI.

Descriptive statistics were used to analyze general characteristics of the study population. Incidence rates and 95% confidence intervals (CI) were estimated for each clinical service. To calculate HAI

incidence, we used the marker day-person at risk, an incidence marker that estimates the days the subject is free of a given event, in this case HAI; $p < 0.05$ was accepted as statistically significant.

To study the relationship between potential risk factors and HAI episodes, we obtained odd ratios (OR). To evaluate their significance, we estimated 95% CIs. variables that showed significance in bivariate analysis were modeled through a multivariate logistic regression to obtain OR. New 95% CIs were calculated to test significance of these estimators. Statistical relevance of the final model was evaluated through a Hosmer and Lemeshow χ^2 test.

HAI direct care costs (DCC) are costs associated with hospitalization and include cost evaluation per hospitalization day, antibiotic administration, medical interventions, diagnostic tests and medical supplies (Pan American Health Organization: Protocol OPS/HCP/HCT/16/00). In order to estimate DCC, we carried out a partial cost analysis expressed in US dollars (USD). Therefore, we investigated costs of diagnostic tests and therapeutic procedures as well as those caused by an extended hospitalization secondary to HAI. Analysis of direct costs included estimation of overall costs and day/bed cost; other variables analyzed were antibiotic administration, second surgeries, treatments, professional visits, need to isolate or transfer the patient to a more specialized facility. All gathered data were entered into a database that was later analyzed using Stata v9.0 software.

Results

Overall incidence rate for HAI was 9.1/100 days-person-at risk. Within this period, we identified 51 HAI cases (74.5% male and 25.5% female) ($p = 0.000$). Of these patients, 58.8% were <1 year old, with a significant difference regarding other groups ($p = 0.000$). Because cases were matched by age and gender with controls, we found no significant differences in distribution by gender or age group. Distribution by clinical service showed a discreet but significant difference (p =0.0076), with the PICU having the highest rate (37.3%). We observed that bloodstream infections (BSI) were the most frequent HAIs (52%) followed by pneumonias (18%) and urosepsis (8%).

Regarding the bivariate analysis of risk factors, we identified that length of hospital stay >7 days [OR = 17.0, 95% CI (2.10-31.26)]; catheter usage [OR = 9.7, 95% CI (2.30-18.61)]; assisted mechanical ventilation [OR = 6.6, 95% CI (2.15-10.51)]; CVC insertion [OR = 4.9, 95% CI (1.79-8.38)]; and low weight for age and gender [OR = 3.9, 95% CI (1.82-10.73)] increased HAI risk. Other variables such as age, gender and antibiotic administration showed no relationship with HAI.

Five variables that showed statistical significance in bivariate analysis were analyzed through multivariate logistic regression. This showed that the only variables that maintained their significance were length of hospital stay >7 days, which doubled its weight (OR = 34.1, 95% CI 5.2-59.93); catheter usage remained practically even (OR = 10.2, 95% CI 3.34-17.65) and insertion of CVC increased its weight (OR = 7.5, 95% CI 2.24-12.36). The overall model demonstrated to be statistically significant ($\chi^2 = 133.45$, $p < 0.0001$) (Table 1).

A preliminary step to analyze HAI direct cost was to identify clinical procedures carried out on hospitalized patients. We observed that each patient presented HAI during 10.8 days on average; this mean was higher (13.3 times) in patients hospitalized in the ICU, which was the service where more external devices were used (catheters, tubes, cannulae, ventilators and solutions). We observed 26.3 devices were used on average in HAI patients as well as 31.9 laboratory tests per patient. Internal medicine service prescribed the highest number of antibiotic units for HAI (20.4 units per patient). Finally, there were no major differences in cultures (two per case) and clinical studies (three per patient) (Table 2).

As for overall costs, hospitalization of HAI patients implied a total cost of $19,025 USD (an average cost of $365 USD per patient). Of costs, DCC reached $10,684 USD (56.2%). Each HAI episode

represented an average cost of $200 USD. Of DCC costs, 57% ($6,090 USD) was associated with days/bed being the average cost per day/bed equivalent to $117 USD. It is important to mention that this cost was associated only with the period the patient presented HAI and not the patient's entire length of hospital stay. Laboratory tests represented the second highest cost procedures, reaching 23.3% ($2,493 USD) DCC of HAI. These were followed by medical devices (7.8%) and antibiotic usage (6.1%). Actually, the average cost per patient for laboratory tests reached $47 USD, whereas medical device use reached $16 USD. Average costs per procedure and patient are shown in Table 3.

According to our observations, 62.3% ($6,658 USD) of HAI DCC were generated at the PICU, where days/bed represented 67.5% ($4,493 USD) of total cost of clinical service (Table 4). Infectology service represented 22.7% ($2,235 USD) of costs, whereas internal medicine contributed with the remaining 15.3% ($1,596 USD). As previously mentioned, average DCC per HAI case reached $200 USD; however, this cost was higher when the episode occurred at the PICU ($350 USD). Infectology reported $152 USD and internal medicine reported $100 USD as average DCC. Therefore, DCC at the PICU were >200% higher than in other services (Figure 1).

Discussion

The most significant findings in this study show that in addition to an extended hospital stay, use of catheters and tubes significantly contributed to HAI risk.

Table 1. Multivariate model for HAI risk-associated factors* in patients hospitalized at three clinical services (HIES, October 1, 2007–January 31, 2008)

Variable	OR**	SE	95% CI
Extended hospital stay [>7 days] (1 = yes; 0 = no)	34.1	0.82	(5.21-59.93)
Catheter usage (1 = yes; 0 = no)	10.2	0.75	(3.34-17.65)
CVC insertion (1 = yes; 0 = no)	7.5	0.67	(2.24-12.36)
Low weight for age and gender (1 = yes; 0 = no)	4.9	1.71	(0.17-14.60)
AMV (1 = yes; 0 = no)	0.1	1.35	(0.00-0.94)

*Based on a sample with 192 subjects (51 cases y 141 controls).
**Adjusted for variables included in model.
Results of hypotheses test for final model: likelihood ratio (LR) c^2 = 133.45 (1 DF); p <0.0001.
AMV, assisted mechanical ventilation; CVC, central venous catheter; HIES, Hospital Infantil del Estado de Sonora; OR, odds ratio; CI, confidence interval; SE, standard error.

Table 2. Average number of medical interventions in patients with HAI according to clinical service (HIES, October 1, 2007-January 31, 2008)

Clinical service	Hospital stay (days)	Length of stay with HAI (days)	Lab tests	Antibiotics	Medical devices*	HAI cultures**	Other medical procedures for HAI***	Clinical studies during HAI
Infectology	38.9 (26.3)[a]	11.9 (3.4)	27.8 (1.8)	10.2 (2.8)	24.5 (4.3)	2.1 (0.5)	33.4 (5.7)	2.9 (1.0)
Internal medicine	44.0 (39.9)	7.3 (2.9)	17.2 (2.3)	20.4 (2.3)	18.6 (3.5)	1.8 (0.5)	18.1 (4.4)	2.5 (1.2)
PICU	51.7 (27.1)	13.3 (2.7)	31.9 (4.5)	13.8 (3.9)	26.3 (4.7)	2.0 (0.9)	44.9 (6.8)	3.0 (2.1)

*Catheters, tubes, cannulae, mechanical ventilators and solutions.
**Blood, urine, cerebrospinal fluid, catheter tip, Foley catheter, nasogastric catheter, secretions, silastic.
***Venous puncture and medical supplies.
[a]Average number of interventions (standard deviation).
HAI, hospital-acquired infections; PICU, pediatric neonatal intensive care unit; HIES, Hospital Infantil del Estado de Sonora.

This was observed after controlling some biological variables (weight at admission, age) and other medical procedures such as use of assisted mechanical ventilation, antibiotic administration, parenteral nutrition and nebulizers. Extended hospital stay represented that 56% of overall hospitalization costs were attributable to HAI care. Our study findings corroborate the relationship between risk factors and HAI incidence in the pediatric population because these events are frequently associated with professional practices of health care personnel and hospital infrastructure.[9] Therefore, HAI rate may be used as a care-quality marker for hospitalized patients. Its estimation helps determine not only the costs associated with a given disease but also highlights the impact on institutional budgets.

The average cost per HAI episode was $2062 USD. We found that this is lower than that reported

Table 3. Direct, total and average costs according to different procedures in medical care of HAI patients (HIES, October 1, 2007-January 31, 2008)

Procedure	Average per patient	Total procedures	Average cost per procedure*	Average cost per patient*	Total cost*
Hospital stay (days)	44.9	2308	84.84	3,761.19	195,581.79
Hospital stay associated with HAI (days)	10.8	559	111.99	1,203.97	62,606.42
Laboratory tests	20.3	1057	24.25	493.01	25,636.31
HAI associated antibiotics	14.4	751	8.92	128.81	6,698.10
Medical devices1	21.7	1127	7.59	164.56	8,556.97
Cultures2	1.9	101	31.31	60.82	3,162.75
Other medical procedures3	32.3	1678	0.77	24.72	1,285.47
Clinical studies	2.75	143	13.26	36.46	1,895.91

[1]Catheters, tubes, cannulae, mechanical ventilators and solutions.
[2]Blood, urine, cerebrospinal fluid, catheter tip, Foley catheter, nasogastric catheter, secretions, silastic.
[3]Venous puncture, medical supplies.
*Estimated costs in USD on May 22, 2008 (exchange rate: 10.3644 MXN per 1 USD).
HAI, hospital-acquired infection; HIES, Hospital Infantil del Estado de Sonora.

Table 4. Direct care costs for HAI according to clinical service (HIES, October 1, 2007-January 31, 2008)

	Infectology	Internal medicine	PICU	Total
Total hospitalization cost*	52,525.73	63,855.25	79,200.82	195,581.79
Direct cost attributable to HAI*	24,979.40	16,410.02	68,452.53	109,841.94
Days/bed due to HAI	10,209.37	6,200.46	46,196.60	62,606.42
Laboratory tests	8,757.86	5,403.11	11,475.34	25,636.31
HAI antibiotics	1,385.55	1,129.06	4,183.49	6,698.10
Medical devices1	2,677.15	1,648.60	4,231.22	8,556.97
Cultures2	1,101.85	981.24	1,079.66	3,162.75
Other medical procedures3	413.43	290.15	581.90	1,285.47
Clinical studies	434.18	757.40	704.33	1,895.91
Average cost* per HAI case	1,565.43	1,025.63	3,597.69	2,062.92

[1]Catheters, tubes, cannulae, mechanical ventilators and solutions.
[2]Blood, urine, cerebrospinal fluid, catheter tip, Foley catheter, nasogastric catheter, secretions, silastic.
[3]Venous puncture, medical supplies and interhospital consultations.
*Estimated costs in US dollars on May 22, 2008 (exchange rate: 10.3644 MXN per 1 USD)
HAI, hospital-acquired infections; HIES, Hospital Infantil del Estado de Sonora.

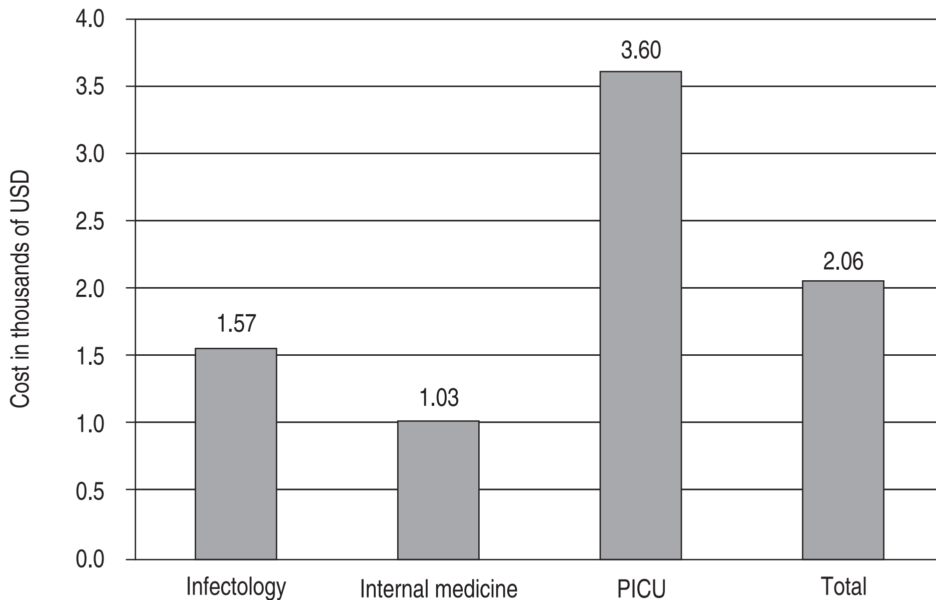

Figure 1. Average cost per hospital-acquired infection (HAI) in three clinical services from Hospital Infantil del Estado de Sonora between October 1, 2007 and January 31, 2008.

in similar studies in Mexico. One of the studies reported an average cost of $8,990 USD,[10] whereas Higuera et al. reported an average cost of $10,424 USD per BSI episode associated with catheter usage.[11] One possible explanation for this difference is that those studies included only ICU hospitalized patients where costs are increased considerably because of the technological and medical complexities such patients require.

This was corroborated in our study because HAI average cost in the ICU ($3597 USD) was 3.5 times higher than if the episode had place in the internal medicine service and 2.3 times higher than a HAI episode in the service of infectology. When we included patients from different clinical services, average cost diluted considerably, although DCC range was between $240.94 and $11,110.60 USD. The latter was observed in a patient with nosocomial BSI in the ICU.

One of the main effects of HAIs is that they extend length of hospital stay up to three times, increasing the average stay from 7 to 21 days, which contributes to costs increments, independently of HAI diagnosis and hospital service used. For instance, Jarvis reported, in 1996, that the average cost associated with urinary tract infection (UTI) was $593, $2,734 for surgical wounds, $4,947 for pneumonias, and between $3,061 and $40,000 for BSI (expressed in USD).[12]

These costs are very different from DCC identified in our study. For example, a BSI episode had an average cost of $2219.18 USD; pneumonia $3174.34 USD; and UTI $2078.53 USD, whereas other types of HAI had an average cost of $1361.64 USD. Such differences are difficult to clarify because HAI cost calculation is very complex and is subordinated to research goals so comparisons should be carefully examined before reaching conclusions.

However, there is one possible explanation for the differences observed in this study. In general, to estimate HAI cost there are two possible scenarios: (a) studies that attribute cost according to estimation from an expert group about resources needed for HAI care (e.g., hospitalization days, antibiotics and other consumables) and (b) comparative studies that determine cost from resource use in HAI patients and compare it with other groups of patients.[13]

The study by Jarvis[12] indicated average costs attributed to morbidity and mortality from HAI, whereas our study was comparative and, therefore, results cannot explain the event in the same way. Therefore, even when comparative studies have

higher precision and rigorous methodology, their execution is not easy because the control matching procedure is arduous and its appropriate accomplishment is not always possible. This may produce bias, even when using computed records from medical files. On the other hand, they depend greatly on the quality of hospital data for certain variables. This is possibly another explanation we can offer to try to understand the significant differences observed between this study and other published studies.

Moreover, there were other operational difficulties that could contribute to DCC underestimation. For instance, consumables and medication costs provided by the Department of Financial Resources in our hospital[1] was noticeably lower than the average consumer price. In 2006, according to the Office of the President of the Mexican Republic, the price per 500 mg ampicillin solution flask was $2.00 USD. However, the price in 2008 was only $0.62 USD. Other price differences include[2] that 500 mg amikacin solution has an average consumer price of $18.22 USD, whereas the cost for our hospital was $0.31 USD. A 1-g injectable dose of cefotaxime has a consumer price of $15.80 USD *vs* $0.91 USD for our hospital and, finally, 500 mg injectable vancomycin has an average consumer price of $26.50 USD compared to $5.70 USD in our hospital. Such differences may have produced a DCC underestimation for HAI in our institution. Involvement and support from administrative personnel is essential when evaluating HAI-associated costs and analyzing the financial burden of the event.

On the other hand, the incidence we observed (9.1/100 days-person) is similar to that published in other pediatric HAI Mexican studies such as the multicenter study by Avila-Figueroa et al. that found a 9.8% incidence14 or the study by Tinoco et al. who reported a prevalence of 9%.15 We observed a lower prevalence than Hospital Infantil de Mexico, which reported an incidence of ~20%.16 It is possible that the differences are due to the fact those study was carried out only in the ICU, which can be associated with a higher HAI risk.

Despite the previously mentioned information, there were noticeable differences in the nature of the HAI because Tinoco et al. reported omphalitis as the first cause, with only 12% of cases associated with BSI and 4.5% of cases associated with pneumonia. The study by Avila-Figueroa et al. reported that pneumonia represented 25% of HAI, 19% were due to BSI and 5% were due to UTIs. In our study we found that BSI represented 51% of HAI followed by pneumonia (18%) and UTIs (8%). UTIs were less frequent in our sample when compared with other studies (particularly from the U.S.) because in some hospitals they represent up to 60% of HAI incidence.[17,22]

Regarding potential HAI risk factors, we found three factors were associated with the event: (a) extended length of hospital stay (>7 days); (b) urinary/nasogastric catheters usage; and (c) CVC usage. As for extended hospital stay, its effect may be associated with a higher exposure for patients with nosocomial pathological agents as well as an increased number of medical procedures.[18] However a potential limitation in our findings is that we did not control the effect of number of hospitalization days when selecting controls; therefore, it is possible that this variable is overestimated. However, even when this factor is recognized in HAI prevalence,[19] we recommend caution when interpreting our findings and carry out new investigations that control this effect even in our institution.

Regarding the second factor, use of Foley catheter increases the risk of urosepsis and death as well as a higher antibiotic administration, bacteria resistance and increased costs for hospital stay.[20] We have also observed that most UTIs associated with catheters are unnoticed and they produced the largest number of antibiotic-resistant bacteria in the hospital.[21]

It is accepted that when using catheters, pathogen entrance is secondary to three procedures: location of insertion, circuit interruption and device contamination.[22] All of these mechanisms involve physicians and nurses. Inappropriate handling, lack of proper sanitizing before insertion, a non-hermetic circuit or inappropriate measures when discard-

ing recipient contents are mechanisms that contribute to HAI development. In order to corroborate whether such mechanisms are associated with HAI, it is necessary to carry out specific studies in our hospital, which may reduce financial burden and morbidity produced by nosocomial UTIs.

Regarding use of CVC, this increased HAI risk by 7-fold in studied subjects and has been reported as the chief medical procedure associated with nosocomial BSI in pediatric patients.[23] It has been accepted that CVC affects immune mechanisms in host, neutralizes catheter anti-adhesive properties and increases bacteria survival and antibiotic resistance. All of the above contribute to increased risk of HAI.[24] Some mechanisms that may explain this risk are nonaseptic insertion, excessive length of procedure, catheter contamination and inappropriate handling. In all cases, involvement of appropriate health care personnel is essential to reduce HAI risk associated with this device.

In our study, CVC was applied to 68% of patients who developed HAI, so it is highly convenient to design strategies and activities at HIES to improve its application, care and handling. It seems relevant that new studies are carried out at our hospital to identify adverse events and complications associated with catheter insertion such as catheter displacements or breakages, pneumothorax, gas embolism or lesion of adjacent anatomic structures and late complications (infectious and thrombotic).[25]

In conclusion, the design and execution of studies that examine the role of routine medical procedures in HAI risk and their financial burden on institutional budgets can generate useful information to implement control measures that, on one hand reduce morbidity rate associated with HAI and, on the other hand, contribute to cost reduction.

Studies that evaluate direct costs attributable to HAI are difficult to compare because of method complexity, differences in hospital structure and capacity and even economic differences among institutions. Nevertheless, further studies regarding this subject are being developed systematically in hospitals throughout the state of Sonora and similar methods can contribute positively to generate knowledge for decision-making.

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