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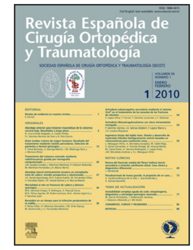

ORIGINAL ARTICLE

Incidence and associated factors of surgical site infections after hip arthroplasty

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KEYWORDS
Surgical wound infection;
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Abstract
Introduction: Prosthetic joint infection after hip arthroplasty is the most feared complication and is responsible for prolonged hospitalisation and an increased risk of morbidity and mortality. To identify the factors involved in its onset may lead to interventions to reduce the risk of infection.
Material and methods: We prospectively reviewed data collected from the health care infection surveillance system (INCLIMECC) on 3067 hip arthroplasties undertaken in the Ramon y Cajal University Hospital between October 1999 and December 2009. Multivariate analysis was performed using logistic binary regression to create mathematical models to predict joint infection after hip arthroplasty.
Results: The overall incidence of joint infection after hip arthroplasty was 2.71%. Unadjusted univariate analysis showed multiple variables associated with joint infection. After multivariable logistic regression analysis, we found the following independent predictors: age, days of hospitalisation prior to the intervention and risk index of the National Healthcare Safety Network (NHSN) ($p < .05$).
Conclusions: NHSN risk index and the days of hospitalisation prior to the intervention are associated to other risk factor of joint infection after hip arthroplasty, such as Diabetes Mellitus, obesity and rheumatoid arthritis. Nevertheless is important to analyse these factors separately to increase the predictive power of the multivariate model.

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PALABRAS CLAVE
Infección de la herida quirúrgica;
Incidencia;
Factores de riesgo;
Artroplastia de cadera

Incidencia y factores asociados a la infección de localización quirúrgica tras artoplastia de cadera

Resumen
Introducción: La infección de localización quirúrgica (ILQ) posterior a artroplastia de cadera es la complicación más temida causando hospitalización prolongada, incremento de morbilidad, mortalidad y altos costes. La identificación de los factores implicados en su aparición puede orientar intervenciones para la reducción del riesgo de infección.
Material y métodos: Los datos de ILQ y sus factores de riesgo fueron prospectivamente recolectados por el sistema de vigilancia de infección asociada a la atención sanitaria INCLIMECC (Indicadores Clínicos de Mejora Continua de la Calidad), a partir de 3.067 procedimientos de artroplastia de cadera realizados en el Hospital Universitario Ramón y Cajal entre octubre de 1999 y diciembre de 2009. Análisis de regresión logística binaria multivariable con el software SPPS versión 15.0 para Windows fue utilizado para la construcción de un modelo predictivo de ILQ.
Resultados: La incidencia global de ILQ fue de 2,71 casos por cada 100 intervenciones. En el análisis univariable, la mayoría de los factores analizados estuvieron asociados al riesgo de infección articular. El análisis de regresión logística multivariable sólo identificó tres factores independientemente asociados a ILQ: edad, estancia preoperatoria e índice NHSN ($p < 0{,}05$).
Conclusiones: Aunque el índice NHSN y la estancia preoperatoria son potenciales marcadores de la presencia de otros factores para ILQ como diabetes mellitus, obesidad, neoplasia y artritis reumatoide, el análisis de éstos por separado podría aumentar el poder predictivo del modelo multivariable.

Introduction

In the developed world, population aging, biomedical technology, and a longer life expectancy for patients with underlying chronic disease are some of the factors that have contributed to the increased number of hip surgeries for patients needing a prosthesis.[1] Infection related to joint replacement is the most serious complication, increasing patient morbidity and raising the associated costs for the healthcare system. In Spain, approximately 30,000 arthroplasties are performed annually, with a surgical site infection (SSI) rate of 3.4%.[2] The impact on hospital stay attributable to infection has been estimated at 31 days in excess of the post-operative stay.[3] In countries such as England, the additional costs attributable to SSI have been calculated at £3.342, with an adjusted mortality rate twice as high in patients with infection.[4] The primary patient-related risk factors for SSI following hip arthroplasty include age, underlying medical conditions, the American Society of Anaesthesiologists (ASA) anaesthesia risk, and a history of revision arthroplasty. Intervention-related factors include simultaneous bilateral arthroplasty, prolonged duration of the surgery, degree of contamination of the surgery, and type of surgery (elective or emergency).[5-10]

In 1997, a healthcare infections surveillance network for surgical patients was created in Spain [Spanish acronym *INCLIMECC, Indicadores Clínicos de Mejora Continua de la Calidad*], based on the NHSN (National Healthcare Safety Network) in the United States, to determine the incidence of endemic infections, to monitor trends, and to compare infection rates among hospitals using standardised criteria. We analysed 3,067 hip arthroplasty surgeries performed in a 1,200-bed acute care hospital in the city of Madrid for the purpose of estimating the incidence of SSI and determining the risk factors associated with it during the post-operative hospital stay.

Materials and methods

INCLIMECC is a prospective system for epidemiological surveillance of nosocomial infections that gathers clinical and surgical information through a validated protocol.[2,11] It is coordinated by the Preventive Medicine Service at Hospital Universitario Ramón y Cajal and headed by a team of epidemiologists and nurses specializing in this field, who visit the Traumatology units every 1 or 2 days to monitor all patients from the time they undergo surgery until they are discharged, including any re-admission for infection.

This work is a retrospective cohort study that included all hip arthroplasties, elective or emergency, performed between October 1999 and December 2009, on subjects over 15 years of age of both sexes, and identified by the International Classification of Diseases, ninth revision, with codes 81.51-81.53.

The NHSN risk index was estimated for each patient who underwent hip arthroplasty. This is a scale of values from 0 to 3, representing the number of risk factors present from among the following: presurgical ASA anaesthesia risk ≥3; surgery classified as contaminated or dirty/infected; and procedure duration of more than 120 minutes.[12] The criteria

Table 1 Cumulative incidence (CM) and incidence density (DN) for surgical site infection (SSI), by risk index

Risk index	No. surgeries	No. SSI	CM[a] (%)	95%CI		No. patient-days	DN[b] (per 1000 p-d)	95%CI	
0	1,606	19	1.18	0.65	1.71	20,987	0.91	0.58	1.42
1	1,313	48	3.66	2.64	4.67	20,595	2.33	1.76	3.09
2/3	148	16	10.81	5.81	15.81	2,983	5.36	3.29	8.76
Total	3,067	83	2.71	2.13	3.28	44,565	1.86	1.50	2.30

[a] Test for linear trend, chi-square=47.56; *P*<.001.
[b] Incidence density expressed per 1,000 patient-days at risk during hospitalisation.

used to define SSI correspond to those defined by the CDC/NHSN,[13] identified through the medical record and the microbiology culture reports. Administration of any of the following antibiotics for not more than 24 hours post-operatively was considered adequate prophylaxis: cephazolin, amoxicillin/clavulanic acid, or vancomycin in patients allergic to the beta-lactams.

The data was subjected to a quality control process whereby its validity was checked, primarily for any inconsistent or missing values, through direct verification of the information on the original record cards from which it was collected.

Statistical analysis

SSI incidence was estimated, through the cumulative incidence, as the raw percentage of surgical interventions that developed an SSI during the surveillance period, and through incidence density, expressed per 1,000 patient-days at risk during hospitalisation. Confidence intervals of 95%(95%CI) were calculated for both estimates.

The variables were described keeping in mind that they fall into 2 categories: quantitative and qualitative. In the first, the statistical normality of the data was evaluated through asymmetry and kurtosis coefficients, at the same

Table 2 Univariate analysis of characteristics related to the patient and the surgery

Variable	Category	N=3,067	%	OR	95%CI		*P* (a)
Sex	Male	1,043	34.0	1			
	Female	2,024	66.0	1.07	0.67	1.70	.773
Age	<75 years	1,510	49.2	1			
	>75 years	1,557	50.8	2.29	1.43	3.69	.001
ASA Classification	1, 2	1,980	64.6	1			
	3, 4	1,087	35.4	3.15	2.01	4.95	<.001
Pre-operative stay	≤3 days	1,621	52.9	1			
	>3 days	1,446	47.2	2.66	1.66	4.28	<.001
Surgery duration	≤75th percentile	2,548	83.1	1			
	>75 percentile	519	16.9	2.30	1.43	3.70	.001
Type of surgery	Elective	2,932	95.0	1			
	Emergency	135	5.0	0.81	0.25	2.59	.723
Arthroplasty	Partial replacement	1,156	37.7	1			
	Total replacement	1,745	56.9	0.58	0.37	0.92	
	Revision	166	5.4	1.22	0.54	2.78	.039
Contamination	Clean/clean-contaminated	3,057	99.7	1			
	Contaminated/dirty	10	0.3	9.18	1.92	43.93	.005
Risk Index	0	1,606	52.4	1			
	1	1,313	42.8	3.16	1.85	5.41	
	2, 3	148	4.8	10.12	5.08	20.15	<.001

Variable	Category	N=3,031	%	OR	95%CI		*P*[a]
Prophylaxis duration	<24 hr	692	22.80	1			
	>24 hr	2,340	77.20	0.78	0.47	1.29	.348

[a] Wald test.

time the appropriate measurements of central tendency and dispersion were calculated. For the qualitative variables, absolute and relative frequencies were obtained in each variable category.

Selection of the variables with potential SSI-risk-prediction effect were evaluated using univariate logistic regression, raw odds ratios being obtained as a measure of the effect of the associations, with their respective 95%CIs and *P* values; the variables selected as possible predictors were those with statistical significance less than or equal to.30 or with theoretical relevance in the literature. In the maximum model, the presence of at least 10 cases of infection per variable in the least likely response category and the absence of collinearity were evaluated. Backward stepwise multivariate logistic regression was used, evaluating the exclusion/inclusion of each variable, using the reasoning test for verisimilitude with a value $P \leq .05$ as significant. Assumptions were checked for absence of influencing remote or atypical values and for equidispersion. The model's calibration and discrimination were evaluated through the Hosmer and Lemeshow goodness-of-fit test and through estimation of the area under the receiver operating characteristics curve (AUC), respectively. Version 15.0 of the SPSS program was used for analysing the data.

Results

Incidence of surgical site infection following hip arthroplasty

Between October 1999 and December 2009, 3,067 hip arthroplasty surgeries were performed on 2,826 patients. Of the SSIs, 40% (33) were superficial incisional infections, 28%(23) were deep incisional infections, and 32%(27) were organ/space infections. The overall cumulative incidence of SSI was 2.71 cases per 100 interventions. The cumulative incidence figures shown in table 1 suggest that the risk of SSI is 9 times higher in interventions with a risk index of 2 or 3 than in surgeries with an index of 0. However, because the surveillance is actively conducted while patients are still in the hospital, this measure of incidence will be affected by the duration of the post-operative stay. The incidence density calculation showed that, although the risk of SSI following hip arthroplasty is still greater with an index of 2 or 3, this was reduced to a little under 6 times that seen in surgeries with an index of 0.

Characteristics related to the patient and the procedure

Women accounted for 2,024 (66%) of the patients who underwent surgery. Their mean age was 73 years (interquartile range 67 to 83). Of the total arthroplasties performed, only 5% were emergency procedures, where osteoarthritis and trauma represented the cause of more than 80% of the arthroplasties performed, with a median surgical duration of 90 minutes (interquartile range 70 to 120). Antibiotic prophylaxis was administered in all cases where it was indicated, the primary cause of inadequacy being its duration, with a median of 3 days (interquartile range 2 to 3).

Table 3 Microorganisms isolated from SSIs

Microorganisms	SSI=83	%
Gram-positive cocci		
Staphylococcus epidermidis	8	9.60
Methicillin-resistant *Staphylococcus aureus (MRSA)*	6	7.20
Staphylococcus aureus	3	3.60
Staphylococcus, other	2	2.40
Streptococcus spp.	2	2.40
Streptococcus agalactiae	1	1.20
Gram-negative bacilli		
Escherichia coli	5	6.00
Pseudomonas aeruginosa	4	4.80
Enterobacter cloacae	2	2.40
Other enterobacteria	11	13.20
Others[a]	1	1.20
Polymicrobial aetiology	38	46.00
Origin unknown	7	8.40

[a]Candida albicans.

Risk factors associated with SSI following hip arthroplasty (table 2)

The raw analysis showed that there was no difference between men and women in terms of the risk of SSI. However, it was significantly correlated to age as well as the pre-operative stay. The risk of infection increased with the ASA classification and the duration of surgery. Although contaminated or dirty surgical cases represented less than 1% of the total, there were 9 times more SSIs in this type of surgery than in clean or clean-contaminated interventions. The SSI risk varied depending on the risk index category, being greater for procedures with an NHSN index of 2 or 3. Analysis of the prophylaxis found no significant reduction in the risk of infection with prolonging the antibiotic beyond 24 hours after completion of the surgery.

Aetiology of the infection

One or more causative microorganisms were identified in 46% of SSIs. Among single-aetiology infections, the Gram-positive cocci: Staphylococcus epidermidis and methicillin-resistant Staphylococcus aureus (MRSA) were the microorganisms most commonly isolated. Gram-negative bacilli as a whole were the first microorganisms identified in 60% of the 76 SSIs analysed (table 3).

Multivariate analysis

The multiple logistic regression analysis found 3 significant variables independently associated with the risk of SSI: age, pre-operative stay, and risk index (table 4). Although the variables of sex and type of surgery exceeded the statistical threshold set in the univariate logistic regression, they were included in the maximum model because of their theoretical relevance as SSI risk predictors. Our multivariate logistic

Table 4 Multivariate analysis of the risk factors for SSI

Variable	Category	OR	95%CI		P[a]
Age	≤75 years	1			
	>75 years	1.80	1.07	3.01	.024
Pre-operative stay	≤3 days	1			
	>3 days	1.80	1.07	3.02	.024
Risk Index	0	1			
	1	2.62	1.52	4.53	
	2, 3	9.48	4.73	18.98	<.001

[a]Reasoning test for verisimilitude.

regression predictive model found that these variables had no significant impact on the risk of SSI. The statistical significance of the Hosmer and Lemeshow test (P=.567) indicates good concurrence between the frequency of infection observed and the frequency expected and, therefore, a good fit for the model. The predictive power, evaluated using the area under the ROC curve (AUC=.733; 95%CI.680 to.787), suggests that the 3 variables discriminate acceptably between infected and non-infected. Its discrimination power is 73.3% of the maximum possible.

Discussion

The estimated SSI rates are similar to those published by other countries and surveillance systems in Europe, with an SSI incidence density of 1.86 cases per 1,000 patient-days at risk during hospitalisation.[14,15] The differences found between systems are more striking when compared using cumulative incidence and less striking when compared using incidence density.

The ASA classification and duration of surgery are typically associated with SSI following hip arthroplasty. In harmony with these observations, raw analysis of the variables estimated a higher risk of infection in patients with a worse ASA classification and longer surgery duration. However, the multivariate analysis suggests that the differences in SSI incidence are better explained by the risk index, which evaluates the presence of these 2 factors together with the degree of contamination in the surgery. This index, proposed by the CDC and widely used by many surveillance systems in Europe, has been involved in previous studies as one of the primary SSI predictors.[7,14] Although this is not a modifiable factor, through a simple calculation it reflects the surgery's complexity, for the ASA classification and, indirectly, the risk index could very likely have been determined by the presence of other medical conditions, such as diabetes mellitus, obesity, associated neoplasm, and rheumatoid arthritis, that pose a risk of SSI but were not evaluated in this study.

The multivariate analysis results suggest that the differences by type of arthroplasty may be explained more by patient-related characteristics and the risk index than by the type of procedure performed. This was demonstrated in the multivariate analysis following exclusion of this variable from the final model. In other published studies, after adjusting for age, ASA, and history of trauma, infection rates were shown to be similar for all types of hip replacement surgery performed.[15]

Other predictors that emerge from our multivariate analysis are age and pre-operative stay. Although the strength of association for these 2 factors was reduced with respect to the univariate analysis, the results obtained reinforced the hypothesis that advanced age independently increases the risk of SSI. We found that patients more than 75 years of age had 80% more risk of infection following hip arthroplasty than those under the age of 75.

Simple analysis of the pre-operative stay indicated that this variable should be considered a possible risk factor associated with SSI incidence, while the risk index-stratified analysis suggested a possible interaction with the index, since the differences in median pre-operative stay between patients with and without infection varied according to the NHSN index level. As a result, the maximum model included a term of interaction between these 2 variables that was subsequently excluded from the final model. The risk of SSI was better explained by a model without interaction, where a pre-operative stay of more than 3 days is an independently associated risk factor for SSI. The non-association between pre-operative stay and SSI risk for a risk index of 2 or 3 may be explained by the small number of surgeries in this stratum, which amounted to no more than 5% of the total.

The importance of the pre-operative stay as a factor associated with SSI has been discussed previously in the CDC's guides to prevention of SSI, where it is established that this variable may play a role as a marker for other factors involved in SSI, such as the severity of the disease and the presence of co-morbidities.[16,17] Pre-operative antibiotic prophylaxis is a mainstay of SSI prevention, and there is agreement as to the importance of adequate tissue levels of antibiotic at the moment the incision is made. Essentially, initiation of antibiotic prophylaxis appears to be the most important factor.[18,19] INCLIMECC posed limitations on collection of this information, because of which the evaluation of its adequacy was restricted to the choice of antimicrobial agent and its duration. The primary cause of inadequacy was prolonging the duration of antibiotic prophylaxis for more than 24 hours after completion of the surgery. Our raw analysis found no significant reduction in the risk of infection with prolonging the antibiotic beyond 24 hours after completion of the surgery.

In a recent Cochrane review on the efficacy of prophylactic antibiotic administration in surgery for closed proximal femur fracture, it was found that the effect of a single dose is similar to that of multiple doses, if the antibiotic chosen remains active during the entire period of time from start to finish of the surgical procedure.[20] However, even though the prolonged administration of prophylactic antibiotics does not increase the infection rate, it is a significant factor in the emergence of resistance to antimicrobial agents.[21-23]

Among the infections of single aetiology, the Gram-positive cocci Staphylococcus epidermidis and MRSA were the microorganisms most frequently isolated. Contrary to the literature, however, the Gram-negative bacilli as a whole were the first microorganisms identified in 60% of the 76 SSIs analysed.

This study has some limitations, as discussed below. First, although the INCLIMECC system enables patients re-admitted for infection to be recaptured, the fact that the surveillance period ends with hospital discharge and there is no subsequent active surveillance means that the true incidence of SSI is underestimated, restricting the validity of the model's infection predictors to the post-operative hospitalisation period.

Second, the number of risk factors included in the study was limited to those collected by the INCLIMECC surveillance system. Although diabetes mellitus, a history of neoplasm, obesity, and rheumatoid arthritis, among other medical conditions involved in development of an SSI, may be reflected in the risk index, through the ASA classification, or in the length of pre-operative stay, separate information on these factors could improve infection risk prediction capabilities in patients who undergo hip replacement surgery.

Sample size could have affected the statistical power in some comparisons. The type of surgery and degree of contamination in the surgery were included in the multivariate analysis because of their potential value as predictors of SSI risk. Following the stepwise selection, they were excluded from the definitive model due to the low proportion of some of their categories, which represented no more than 5% in the emergency or dirty surgical procedures.

Evidence level

Evidence level III.

Protection of human and animal subjects

The authors declare that no experiments were performed on humans or animals for this investigation.

Confidentiality of data

The authors will declare that they have followed the protocols of their work centre on the publication of patient data and that all the patients included in the study have received sufficient information and have given their informed consent in writing to participate in that study.

Right to privacy and informed consent

The authors declare that no patient data appears in this article.

Conflict of interest

The authors declare no conflict of interest.

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