

Nosocomial Infections in Surgical Patients at a Central Academic Hospital in South Africa

Hassan Nazeerah, De Oliveira Bianca, Fraser Simon, Govender Sameshan, Madzinga Maano, Mpati Nokolinah, Rahiman Fathima-Zahra, Kalla Zahra, Malebati William Khabe, Luvhengo Thifhelimbilu Emmanuel*

Department of Surgery, University of the Witwatersrand, Johannesburg, Republic of South Africa

Email address:

nazeerah96@gmail.com (H. Nazeerah), biancadeoliveira28@gmail.com (De O. Bianca), thefraserking@gmail.com (F. Simon), sameshan.govender1@gmail.com (G. Sameshan), maano.madzinga@gmail.com (M. Maano), nokolinah.mpati@students.wits.ac.za (M. Nokolinah), fzr101@gmail.com (R. Fathima-Zahra), zahrakalla786@gmail.com (K. Zahra), william.malebati@gauteng.gov.za (M. W. Khabe), Thifhelimbilu.luvhengo@wits.ac.za (L. T. Emmanuel)

*Corresponding author

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Abstract: Nosocomial infections are infections that develop after 48 hours of admission or within 30 days of discharge from a healthcare facility. The aim of the study was to investigate the rate of occurrence and types of nosocomial infections in patients admitted to the surgical wards. An audit based on records of patients who developed nosocomial infections was conducted. Data extracted included patients' demography, comorbidities, the organisms cultured, and their resistance patterns. A total of 574 records from 421 patients were found. Seventy percent (69.8%: 294/421) of the patients were males and 66.3% (279/431) were less than 51 years old. Ninety-four (22.3%: 94/421) patients were found to have polymicrobial infections. The records included 62 species of bacteria and 7 candida species. Around 74.7% (429/574) of the cultured organisms were ESKAPE pathogens. The most cultured organism was *K. pneumoniae* at 18.6% (107/574). Fifty-one percent of the cultured bacteria were resistant to antimicrobials. The overall rate of nosocomial infection was 8.7% with an incidence density of 468.20 per 100 000 patient days. Nosocomial infections were more prevalent in vascular, trauma and neurosurgery patients.

Keywords: ESKAPE Pathogens, Nosocomial Infection, Prevalence, Resistance, Surgical Patients

1. Introduction

A nosocomial infection is a local or systemic infection that develops after 48 hours following admission or within 30 days of discharge from a healthcare facility [1]. Around 1.7% to 46% of patients admitted in healthcare facilities develop nosocomial infections [1, 2]. Nosocomial infections are associated with an increase in morbidities, mortalities, and overall cost of healthcare [3, 4]. Additionally, nosocomial infections are often associated with the emergence of resistant organisms [5].

Nosocomial infections are caused by bacteria, fungi, viruses, and parasites but bacteria are responsible for more than 95% of the infections [1, 6]. The commonly involved

bacteria include *E. faecium*, *S. aureus*, *K. pneumonia*, *P. aeruginosa*, *A. baumannii*, and *Enterococcus species* which are the so-called ESKAPE pathogens. Less than 5% of nosocomial infections are caused by Candida species [1, 7, 8]. Gram-negative bacteria currently account for more than 60% of nosocomial infections [2].

The common nosocomial infections in surgical patients include surgical site infection, catheter associated infection primary blood stream infection, lower respiratory tract infection, urinary tract infection and gastrointestinal tract infections [9, 10]. Monitoring of the occurrence of nosocomial infections is either conducted passively as an audit of records of diagnosed patients or through active surveillance of patients during their stay in a hospital facility.

Active surveillance followed by reporting of nosocomial infections is preferable and has been made mandatory in some countries [11, 12].

The rate of occurrence of nosocomial infection is variably reported and includes point prevalence in admitted patients, number of infections per 1000 patient-admission days or per 100000 patients-bed days/device-days [2, 10, 12]. Nosocomial infections are more prevalent in low- and middle-income countries [13]. The aim of the study was to determine the prevalence of culture proven nosocomial infections in surgical patients. Furthermore, the proportional prevalence of individual organisms and their resistance patterns were also studied.

2. Materials and Methods

Permission to conduct the study was received from the Human Research Ethics Committee of University of the Witwatersrand (M190850) and the Research Review Board of Charlotte Maxeke Johannesburg Academic Hospital (CMJAH). The study was also registered with the National Health Research Database of South Africa. The study was conducted in accordance with The Code of Ethics of the World Medical Association.

This study was a retrospective analysis of the Surgical Functional Business Unit, Infection Prevention Committee (IPC) and Research Electronic Data Capture (REDCap) records investigating the prevalence, causative organisms, and characteristics of the cultured pathogens, associated risk factors and outcome of nosocomial infections in surgical patients at CMJAH. Total admission and average bed occupancy rate, average length of hospital stay, and overall death rates were also collected. The CMJAH is a 1088 bedded central academic hospital in Johannesburg which serves the population from the South of the Gauteng Province of South Africa.

The records which were studied were of patients who were 18 years and older who were admitted to the surgical wards of Trauma ICU, General Trauma Ward, Breast and Endocrine Ward, Vascular Ward, Surgical Gastroenterology and

Neurosurgery Ward between the 1st of January 2018 to the 31st of December 2018. Neurosurgery and Trauma included patients who were admitted to intensive care unit (ICU). Neurosurgical patients were managed in one ward which had an ICU section whereas Trauma Unit had a dedicated ICU ward. The study focused only on infections which were confirmed following microbiological investigations. Patients who had infection during admission and those whose records were incomplete were excluded.

The data extracted from the REDCap and IPC databases were collected and entered onto an Excel spreadsheet. The chi-square test was used to compare two sets of categorical data. An unpaired t-test was performed to see if there was a significant difference in the ages between individuals who had cultured one type of organism and individuals who cultured more than one type of organism. The statistical analyses were performed using the Statistica package, Microsoft Excel (version 16.0.6742.2048 (2019)). The level of significance was set at a p-value below 0.05.

3. Results

A total of 10891 patients were admitted during the study period. The average length of stay during the period was 35.4 days for Trauma Wards, 13.3 days for Neurosurgery Ward, 7.9 days for Surgical Gastroenterology and 5.0 days for the Breast & Endocrine Ward. Six hundred and sixty-four (664) records of nosocomial infections were found and after exclusion, 574 infections in 421 patients were deemed to be suitable for further analysis. The burden of nosocomial infection per patient was therefore 1.36. Three hundred and nineteen (75.8%: 319/421) patients who were diagnosed with nosocomial infections were black Africans, 18.5% (78/421) were whites, 3.0% (17/421) were of Indian descent and 2% (8/421) were of mixed ancestry. Two hundred and ninety-four (69.8%: 294/421) patients were male with a male to female ratio of 2.3:1. The median age of patients who developed nosocomial infection was 45 years. Around 66.3% (279/421) of the patients who developed nosocomial infections were below the age of 51 years (Figure 1).

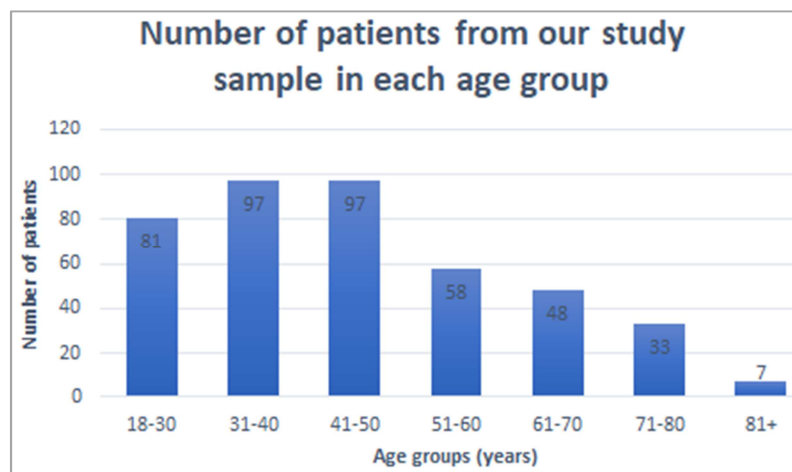


Figure 1. Breakdown of patients who developed nosocomial infection by age categories.

One Hundred and fourteen (19.9% - 114/574) and 18.1% (104/574) of the records were results of microscopy of specimens taken from pus swab and blood, respectively (Table 1).

Overall, 69 species of pathogens were recorded of which seven were candida species. No virus or parasite was reported. The overall prevalence of nosocomial infection was

8.7% among the 10891 patients who were admitted during the study period. The incidence density of nosocomial infections was 468.20 per 100 000 patient-admission days. The prevalence of nosocomial infection for Vascular Ward was found to be 17.4%, Neurosurgery Ward 13.7%, Trauma Wards 6.6%, Breast & Endocrine Ward 4.0%, and Surgical Gastroenterology Ward 2.0% (Figure 2).

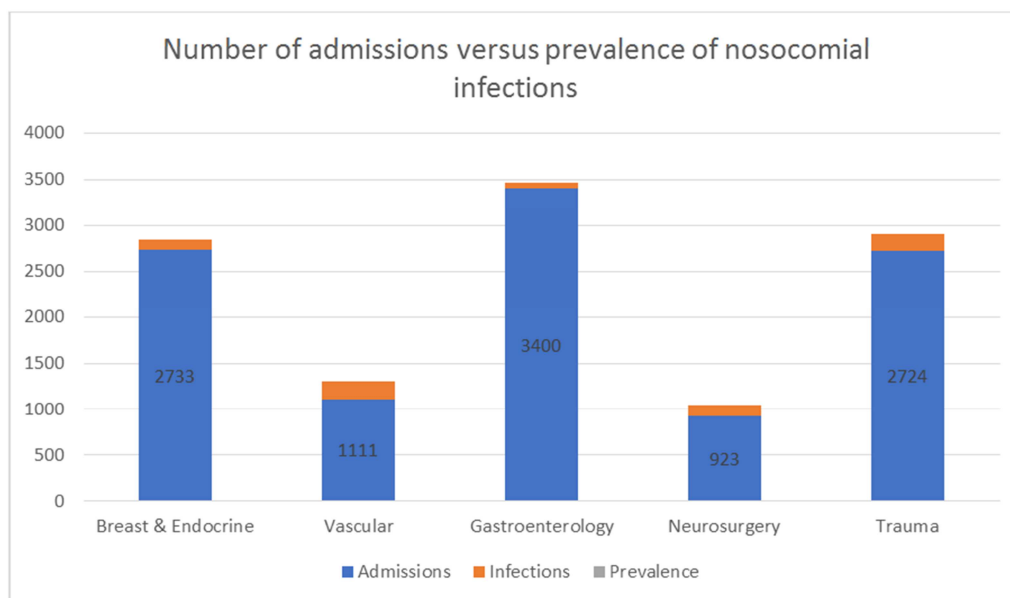


Figure 2. Comparison of the proportion of admitted patients who developed nosocomial infections across studied specialties.

Three hundred and thirty-one (57.7%: 331/574) of the organisms cultured were ESKAPE organisms, which rose to 74.7% (429/574) when *E. coli* and *Proteus species* were added. One hundred and seven (18.6%: 107/574) and 15.0% (86/574) of culture results showed *K. pneumoniae* and *A. baumannii*, respectively (Table 2).

The most common type of pathogen cultured in the female patients was *K. pneumoniae* at 19.9% as compared to 17.9% from males. The difference was however not statistically significant with a p-value of 0.213. Close to 11.4% of nosocomial infections which were caused by *K. pneumoniae* and 11.2% of *A. baumannii* were from individuals below the age of 51 years. The influence of age in the occurrence of nosocomial infections due to the two pathogens was statistically significant (p-value=0.0225) (Table 3).

One hundred and sixty-five (39.2%: 165/421) patients who developed nosocomial infection had comorbidities and 13.3% (56/421) among them had two comorbidities whereas 2.6% (11/421) had three comorbidities (Table 4).

Eighty (19%: 80/421) patients had hypertension, 12.8% (54/421) were HIV positive and 10% (42/421) had diabetes mellitus.

Ninety-four (21.8%: 94/421) patients had polymicrobial infections. Sixty-five (69.1%: 65/94) patients who had nosocomial infections were male with a median age of 47 years as compared to 49 years for the female group. Fifty percent (47/94) of polymicrobial nosocomial infections

demonstrated resistance to antimicrobials. The median age of patients who had monomicrobial infections was 43 years and those who had polymicrobial infection was 47.5 years and the difference was statistically significant with a p-value of 0.0189.

Two hundred and ninety-four (51.2%: 294/574) of the reported infections were resistant to antimicrobials. The organisms which showed the highest antimicrobial resistance was *A. baumannii* at 12.1% and was followed by *K. pneumoniae* at 10.8%. The reported resistance pattern included 15% carbapenem-resistant *Enterobacteriales* (CRE), 43% (ESBL), 10% multi-drug resistance (MDR), 8% meticillin resistant *S. aureus* (MRSA) and 24.2% extensively drug-resistant (XDR). The top-5 reported resistance pathogens were *A. baumannii* XDR, *K. pneumoniae* ESBL, *A. baumannii* MDR, *K. pneumoniae* CRE and *E. coli* ESBL.

In Trauma Wards, the commonest organisms which were isolated were *S. aureus* and *P. aeruginosa*, and 46.6% of organisms which were cultured were resistant. From the Breast and Endocrine Ward, the top two organisms cultured were *S. aureus* and *E. coli*, with a resistance rate of 50%. The predominant organisms in the Vascular Ward were *A. baumannii* and *P. aeruginosa* and 43.5% were resistant to antimicrobials. The surgical gastroenterology unit cultured predominantly *E. coli* with much lower but not insignificant rates of *P. aeruginosa* and *K. pneumoniae*; and 42.9% of organisms isolated showed resistance. The two most recorded

organisms from patients in Neurosurgery Ward were *A. baumannii* and *K. pneumoniae* and 41.8% of the organisms cultured were resistant.

Of the patients who had no comorbidities, 26.1% (24/92) had more than one genus of pathogens isolated as compared to 30.6% (33/108) in those who had one comorbidity, 35.9% (14/39) in those with two co-morbidities and 22.2% (2/9) in cases of three or more comorbidities; and the difference was not statistically significant with a p-value of 0.674. Forty-nine percent (48.9%; 45/92) of the nosocomial infections in patients who had no comorbidities were due to resistant organisms as compared to 36.4% (3/9) in those who had three or more comorbidities. The influence of number of comorbidities on the resistant pattern was statistically significant with a p-value of 0.00757 (Table 3).

The overall mortality in the surgical wards in 2018 was 8.7% out of 10891 patients who were admitted. The mortality rate amongst patients who had nosocomial infection was 15.7%. Mortality in females who had nosocomial infection was 12.4% (16/129) and 16.4% (50/305) for males, and the difference was statistically significant (p-value=0.00038). The mortality rate among black Africans was 13.5% (44/327), 7.1% (1/14) for

Indians, 10% (1/10) for Coloured patients and 24.1% (20/83) for whites. The difference in death rates among racial groups was not statistically significant with a p-value of 0.167. Mortality among patients who had no comorbidities was 8.8% (8/91), 8.3% (9/109) in those who had one comorbidity, 12.8% (5/39) for two comorbidities and 11.1% (1/9) for those who had three or more comorbidities. The influence of number of comorbidities on mortality was not statistically significant with a p-value of 0.78.

Table 1. Type of specimens collected and sent for confirmation of nosocomial infection.

Specimen type	Number (%)
Pus	114 (20.7%)
Blood	104 (18.9%)
Fluid	86 (15.6%)
Urine	80 (14.5%)
Tissue	78 (14.2%)
Tracheal aspirate	30 (5.4%)
Stools	28 (5.1%)
Sputum	27 (4.9%)
Other	4 (0.7%)
TOTAL	551 (100%)

Table 2. Comparison of causative organisms of nosocomial infections based on gender (N=574).

Organism	Females (%)	Males (%)	Total (% Overall)
<i>K. pneumoniae</i>	37 (34.6%)	70 (65.4%)	107 (18.6%)
<i>A. baumannii</i>	16 (18.6%)	70 (81.4%)	86 (15.0%)
<i>E. coli</i>	27 (36.5%)	47 (63.5%)	74 (12.9%)
<i>S. aureus</i>	23 (44.2%)	29 (55.8%)	52 (9.1%)
<i>P. aeruginosa</i>	16 (32.7%)	33 (67.3%)	49 (8.5%)
<i>Enterobacter</i> species	10 (27.0%)	27 (73.0%)	37 (6.4%)
<i>Proteus</i> species	8 (30.8%)	18 (69.2%)	26 (4.5%)
<i>Candida</i> species	6 (28.6%)	15 (71.4%)	21 (3.7%)
<i>M. morgani</i>	5 (41.7%)	7 (58.3%)	12 (2.1%)
<i>S. epidermidis</i>	2 (22.2%)	7 (77.8%)	9 (1.6%)
Other	33 (32.7%)	68 (67.3%)	101 (17.6%)
TOTAL	183 (31.9%)	391 (68.1%)	574 (100%)

Table 3. Distribution of cultured organisms according to age groups (N=574).

Organisms	<31 years	31-40 years	41-50 years	51-60 years	61-70 years	71-80 years	>80 years
<i>K. pneumoniae</i> (106: 18.5%)	14 (13.2%)	28 (26.4%)	23 (21.7%)	17 (16.0%)	14 (13.2%)	8 (7.5%)	2 (1.9%)
<i>A. baumannii</i> (86: 15.0%)	20 (23.3%)	20 (23.3%)	24 (27.9%)	12 (14.0%)	4 (4.7%)	5 (5.8%)	1 (1.2%)
<i>E. coli</i> (74: 12.9%)	6 (8.1%)	14 (18.9%)	28 (37.8%)	13 (17.6%)	9 (12.2%)	3 (4.1%)	1 (1.4%)
<i>S. aureus</i> (52: 9.1%)	11 (21.2%)	15 (28.8%)	12 (23.1%)	6 (11.5%)	3 (5.8%)	5 (9.6%)	0 (0%)
<i>P. aeruginosa</i> (48: 8.4%)	4 (8.3%)	8 (16.7%)	9 (18.8%)	13 (27.1%)	8 (16.7%)	6 (12.5%)	0 (0%)
<i>Enterobacter</i> (37: 6.5%)	5 (13.5%)	13 (35.1%)	6 (16.2%)	3 (8.1%)	6 (16.2%)	2 (5.4%)	2 (5.4%)
<i>Proteus</i> species (26: 4.5%)	2 (7.7%)	6 (23.1%)	9 (34.6%)	2 (7.7%)	2 (7.7%)	3 (11.5%)	2 (7.7%)
<i>Candida</i> species (21: 3.7%)	2 (9.5%)	6 (28.6%)	5 (23.8%)	3 (14.3%)	1 (4.8%)	2 (9.5%)	2 (9.5%)
<i>M. morgani</i> (12: 2.1%)	0 (0%)	1 (8.3%)	1 (8.3%)	4 (33.3%)	3 (25.0%)	2 (16.7%)	1 (8.3%)
<i>S. epidermidis</i> (9: 1.6%)	4 (44.4%)	1 (11.1%)	3 (33.3%)	0 (0%)	0 (0%)	0 (0%)	1 (11.1%)
Others (n=101)	12 (11.9%)	22 (21.8%)	28 (27.7%)	16 (15.8%)	6 (5.9%)	14 (13.9%)	3 (3.0%)
Total (n=572)	80 (14.0%)	134 (23.4%)	148 (25.9%)	89 (15.6%)	56 (9.8%)	50 (8.7%)	15 (2.6%)

Table 4. Percentage distribution of nosocomial infection cases based on existence of co-morbidities.

Number of comorbidities	Monomicrobial infection	Polymicrobial infection
None	73.9% (68/92)	26.1% (24/92)
One	69.4% (75/108)	30.6% (33/108)
Two	64.1% (25/39)	35.9% (14/39)
Three or more	77.8% (7/9)	22.2% (2/9)

4. Discussion

Among the key findings from the current study were that the overall prevalence of nosocomial infections in the surgical wards was 8.7% with incidence density of 468 per 100 000 patient days. Sixty-five percent of nosocomial infections were diagnosed in patients below the age of 51 years, majority of whom were males. Seventy-six percent of the infections were caused by ESKAPE pathogens, and the two most isolated organisms were *K. pneumoniae* and *A. baumannii*. Just over 51% of the nosocomial infections were caused by resistant organisms which was more likely in patients who had no co-morbidities. *Acinetobacter baumannii* had the highest reported antimicrobial resistance.

The economic cost of nosocomial infections to affected patients and healthcare facilities is immense. Over and above an increase in length of hospital stay, nosocomial infections lead to an increase in both morbidity and mortality. Despite global efforts to reduce the occurrence of nosocomial infection, the prevalence remains high. The main aim of this study was to investigate the rate of occurrence and outcome of nosocomial infections in surgical patients. The study also investigated the type of organisms involved in nosocomial infections and their resistance patterns.

Nosocomial infections are commonly caused by bacteria. Although 62 species of bacteria were cultured 57.7% of nosocomial infections were due to ESKAPE pathogens, and up to 74.7% when *E.coli* and *Proteus species* are included among the *Enterobacteriaceae* [14]. The dominance of ESKAPE pathogens can be likened to what has been reported in prior studies [2, 14]. *Staphylococcus aureus* has historically been the organism that was most commonly associated with nosocomial infections. In keeping with the current trend, most cases of nosocomial infections were caused by gram negative bacteria [15]. However, *S. aureus* was the most cultured causative organisms in nosocomial infections among trauma patients and patients who were admitted to the Breast & Endocrine Ward.

The risk of the development of nosocomial infections is higher in surgical patients especially trauma patients and patients who are admitted to units where there is overcrowding [15]. The patients who are admitted to an ICU are also at heightened risk of development of nosocomial infection [9, 10, 16]. However, what influence the rate of occurrence of nosocomial infections the most is the overall length of hospital stay of the patients [12, 17, 18] and the effectiveness of antimicrobial stewardship program at a facility [9, 18-20].

The risk factors for the development of nosocomial infections include the climatic condition [21, 22], gender and age of a patient [12, 15, 18] and the type of surgery [18]. Nosocomial infections are more prevalent in patients who are HIV positive [15, 22, 23]; have co-morbidities [18, 24, 25] which also include obesity [18, 24-26] and hypoalbuminaemia [27].

The occurrence of nosocomial infections in the current

study mirrored the demographic of the country and appeared not to have been influenced by race. An overwhelming majority of nosocomial infections irrespective of pathogens involved occurred in males. Mekonnen and colleagues also reported a high rate of occurrence of nosocomial infections in males [15].

The overall prevalence of nosocomial infection in the surgical wards was 8.7%, which is slightly lower than in previous reports from setting in other LMICs [15, 28]. The prevalence of nosocomial infection from the current study is higher than the 7.6% reported by Nair and colleagues following a study conducted in the Northern Cape [29]. On the other hand, Alemu et al. found a pooled prevalence of 22.2% from studies conducted in hospitals in Ethiopia [28]. The highest prevalence of nosocomial infections was from patients in the Vascular Ward, which is likely to have been due to a combination of older age, associated comorbidities, and the use of prostheses. Higher rates of nosocomial infections in Neurosurgery and Trauma were expected because some of the patients they managed would have been critically ill and in ICU needing invasive monitoring which placed them at increased risk of infection as reported by Jansen and colleagues in 2021 [10].

Klebsiella pneumoniae was the commonest causative organism isolated in nosocomial infections within our study population across all age groups, proportionally accounting for 18.5% of the total infections. It was also the most cultured organism after a point prevalence study conducted recently at one of the tertiary hospitals in South Africa [29]. In the report by Meatherall et al in 2009 [30], *K. pneumoniae* was however identified as the second most common cause of bacteraemia in both community and hospital-acquired bacteraemia. The second most prevalent cultured organism was *A. baumannii*, which mirrors the finding by Mekonnen and his team [15].

Among the fears associated with nosocomial infections is the emergence of antimicrobial resistance, especially among ESKAPE pathogens and candida species. Fifty-one percent of the organisms cultured in the current study were resistant and the most reported type of resistance was XDR at 31.2%. Similarly, Mekonnen also reported the rate of antimicrobial resistance of cultured organisms in patients who had nosocomial infection above 50% [15].

Patients with controlled diabetes are more at risk of acquiring nosocomial infections whilst in hospital when compared to non-diabetics [31]. The current study showed no statistically significant relationship between the number of comorbidities and the number of organisms cultured or the number of nosocomial infections contracted in the current study. Whilst the presence of a comorbidity did not increase the likelihood of contracting a nosocomial infection, it did influence the number of infections contracted.

Among the limitations of the study include that it was retrospective, and some records were incomplete. The study was based on IPC records which did not include clinical findings as some of the results could have just been due to

colonization. Furthermore, the study only focused on positive microbiology results. Some patients had multiple specimens taken simultaneously from various sites which were counted individually which could account for high number of recorded nosocomial infections in Neurosurgery and Trauma wards. Additionally, in certain cases repeated collection of specimens for microscopy might have elevated the count of nosocomial infections. The outcome of patients was only limited to what happened at the time of reporting.

5. Conclusion

The overall rate of occurrence of nosocomial infection was 8.7% and 21% of the infections were polymicrobial. Nosocomial infections were more prevalent in vascular, trauma and neurosurgery patients. Majority of nosocomial infections occurred in male patients below the age of 51 years. Seventy five percent of the infections were caused by ESKAPE pathogens and less than 11% were caused by gram positive aerobic bacteria. *Klebsiella pneumonia* was the most reported organism which was significantly influenced by age. Patients with more comorbidities were more likely to develop infection with non-resistant pathogens than those with one or no known comorbidities. The overall mortality in patients who developed nosocomial infections at the time of reporting was 16%.

6. Recommendations

Future work should include similar studies with longer follow up periods as well as analysis of factors that influence the occurrence of nosocomial infections. Routine recording of data and research on the efficacy of antibiotic prophylaxis on nosocomial infections should be conducted. Future studies should also investigate the impact of the COVID-19 pandemic on nosocomial infections. Findings from the study may better inform empiric use of antimicrobials and aid in the antibiotic stewardship efforts. The study provides a baseline for target intervention in wards where the rate of occurrence of nosocomial infection is higher.

Authorship and Contributions

- i. *HN*: Literature search, writing of research proposal, application for ethics approval, data collection, data analysis and review of manuscript.
- ii. *FS*: Literature search, writing of research proposal, application for ethics approval, data collection, data analysis and review of manuscript.
- iii. *DOB*: Literature search, writing of research proposal, application for ethics approval, data collection, data analysis and review of manuscript.
- iv. *GS*: Literature search, writing of research proposal, application for ethics approval, data collection, data analysis and review of manuscript.
- v. *MM*: Literature search, writing of research proposal, application for ethics approval, data collection, data

analysis and review of manuscript.

- vi. *MN*: Literature search, writing of research proposal, application for ethics approval, data collection, data analysis and review of manuscript.
- vii. *RFZ*: Literature search, writing of research proposal, application for ethics approval, data collection, data analysis and review of manuscript.
- viii. *WM*: Supervision of literature search, supervision of writing of data analysis and review of the manuscript.
- ix. *LTE*: Conception of idea, supervision of writing of research proposal, supervision of application for Ethics and Research Review Board approvals, supervision of data collection and analysis, drafting and review of manuscript, preparation of manuscript for submission and corresponding author.

Conflict of Interest

All the authors do not have any possible conflicts of interest.

Abbreviations

CMJAH: Charlotte Maxeke Johannesburg Academic Hospital.

CRE: Carbapenem-resistant *Enterobacteriales*.

ESKAPE: Enterococcus faecum, *S. aureus*, *K. pneumoniae*, *A. baumannii*, *P. aeruginosa*, Enterobacter species.

ESBL: Extended-spectrum beta-lactamases.

ICU: Intensive Care Unit.

IPC: Infection Prevention Committee.

MDR: Multi-drug resistant.

MRSA: Meticillin resistant *S. aureus*.

REDCap: Research Electronic Data Capture.

XDR: Extensively drug resistant.

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