

Enterococcus spp. as Emerging Pathogens in Wound Infections: Prevalence, Vancomycin Resistance, Risk Factors and Clinical Outcomes in a Tertiary Care Hospital in Lebanon

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Abstract

Background

Enterococcus species have emerged as important nosocomial pathogens in wound infections, with growing concern regarding antimicrobial resistance and increasing prevalence over time. This study aimed to evaluate prevalence trends, Vancomycin resistance patterns, associated risk factors, and clinical outcomes of *Enterococcus*-associated wound infections in a tertiary care hospital in Lebanon.

Methods

A retrospective observational study was conducted including 1,352 patients with confirmed wound infections between 2018 and 2022. Microbiological identification was performed using the VITEK system, and antimicrobial susceptibility testing was interpreted according to Clinical and Laboratory Standards Institute (CLSI) guidelines. Demographic, clinical, and microbiological data were analyzed.

Results

Enterococcus spp. accounted for 10.8% of wound isolates, with *Enterococcus faecalis* predominating (77%). A progressive increase in prevalence was observed from 2018 to 2021, followed by a slight decline in 2022. Infections were predominantly hospital-acquired and were significantly associated with diabetes mellitus, chronic kidney disease, cancer, and prior antibiotic exposure ($p < 0.05$). The prevalence of vancomycin-resistant *Enterococcus* (VRE) was 21.9%, with higher resistance observed in *Enterococcus faecium*. Patients with *Enterococcus* infections had higher mortality rates compared to non-*Enterococcus* cases.

Conclusion

Enterococcus spp. are emerging pathogens in wound infections, demonstrating an increasing prevalence and significant antimicrobial resistance. These findings highlight the need for strengthened infection control strategies and antimicrobial stewardship programs to limit the growing burden of *Enterococcus*-associated infections.

1. Introduction

Wound infections remain a major clinical challenge, contributing to delayed healing, increased morbidity, and significant healthcare burden worldwide [1, 2]. Several types of infections are below the umbrella of Wound infections including Surgical Site Infections (SSIs), Diabetic Foot Injuries (DFIs), and Chronic wounds. Among these, SSIs are one of the most common healthcare-associated infections, affecting

approximately 1% to 5% of hospitalized surgical patients and leading to prolonged hospital stays, increased costs, and higher mortality rates [3–6].

The microbiological profile of wound infections has evolved over time. While *Staphylococcus aureus* has traditionally been the predominant pathogen, other organisms such as coagulase-negative *Staphylococci* (CoNS), *Escherichia coli*, and *Enterococcus spp.* are increasingly identified [5, 7, 8]. In Lebanon, several studies were done regarding this topic, with two main studies highlighting on the prevalence of different pathogens in this type of infections. In epidemiological data from a tertiary care hospital Chatila and his colleagues showed that *Staphylococcus spp.* were the most frequently isolated organisms, followed by *Enterococcus spp.* and *Escherichia coli* [9], highlighting the growing contribution of *Enterococcus spp.* in wound infections. Another study done by Kawtharani and her colleagues showed different pattern of causal agents with *E. coli* coming first followed by *Klebsiella pneumoniae* and *Staphylococcus aureus*, while *Enterococcus spp.* represents just 3.2% of the population [6]

In recent years, *Enterococcus spp.* has emerged as important nosocomial pathogens, contributing to SSIs, urinary tract infections, and bacteremia [9–11]. Among these, *Enterococcus faecalis* and *Enterococcus faecium* are the most frequently isolated species. Their clinical importance lies not only in their increasing prevalence but also in their ability to survive in hospital environments and spread via healthcare workers and contaminated surfaces. The transition from primarily endogenous infections to documented hospital transmission further emphasizes their role in healthcare-associated infections [10–13].

A major concern associated with *Enterococcus spp.* is their intrinsic and acquired resistance to multiple antimicrobial agents, making infections difficult to treat [14, 15]. Of particular importance is the increasing prevalence of vancomycin-resistant *Enterococci* (VRE), which are associated with limited therapeutic options and can lead to persistent hospital outbreaks, posing significant challenges for infection control [16–18].

Despite the growing recognition of *Enterococcus spp.* as emerging pathogens, data on their prevalence trends, prevalence VRE and clinical outcomes, and associated risk factors in wound infections remain limited in Lebanon. Understanding these factors is essential for guiding infection prevention strategies, optimizing antimicrobial stewardship, and improving patient outcomes.

Therefore, this study aims to investigate the prevalence trends of *Enterococcus spp.*, prevalence of VRE, associated risk factors and clinical outcomes in wound infections at a tertiary care hospital in Beirut the capital of Lebanon.

2. Materials and Methods

2.1 Study Design and Ethical Approval

This retrospective observational study was conducted at Al Zahraa Hospital University Medical Center, Beirut, Lebanon, and included patients diagnosed with wound infections between January 2018 and December 2022. This study was performed in accordance with the Declaration of Helsinki, and ethical approval was obtained from the Institutional Review Board (IRB) of Al Zahraa Hospital [Reference Number: 04/2022]. Due to the retrospective nature of the study, the requirement for informed consent was waived, and patient confidentiality was strictly maintained throughout the study.

2.2. Sample size and Data Collection

A total of 1,352 patients with confirmed wound infections were included in the study. Clinical and microbiological data were accessed for research purposes between 01/01/2023 and 31/01/2023 through the hospital laboratory information system (LIS) and medical records database. Patients with positive wound cultures were included, while duplicate isolates from the same patient were excluded to minimize bias.

Data collection encompassed demographic, clinical, and microbiological variables. Demographic data included age and gender. Clinical variables comprised length of hospital stay, infection source (hospital-acquired versus community-acquired), and clinical outcomes (discharge or mortality). Comorbid conditions, including hypertension, diabetes mellitus, coronary artery disease, chronic kidney disease, and cancer, were also recorded.

Information on prior antibiotic exposure before surgery was collected. Microbiological data included the identification of isolated pathogens, characterization of *Enterococcus species*, and assessment of vancomycin resistance profiles.

2.3. Bacterial culture and isolation

Wound samples were collected aseptically using sterile swabs or tissue specimens, depending on the clinical presentation. All specimens were transported promptly to the microbiology laboratory and processed according to standard microbiological procedures.

Samples were inoculated onto appropriate culture media, including blood agar and MacConkey agar, and incubated aerobically at 35–37°C for 24–48 hours. Additional selective media were used when clinically indicated.

Bacterial identification was performed using conventional biochemical methods and confirmed using the automated VITEK 2 system (bioMérieux, France), following the manufacturer's instructions, ensuring accurate species-level identification.

Antimicrobial susceptibility testing was carried out using the same automated system and/or disk diffusion method, and results were interpreted according to the guidelines of the Clinical and Laboratory Standards Institute (CLSI). Vancomycin resistance among *Enterococcus* isolates was determined based on standard CLSI breakpoints.

2.4. Statistical Analysis

Data were entered and analyzed using SPSS software (version 23.0). Continuous variables were expressed as mean $\pm$ standard deviations (SD), while categorical variables were presented as frequencies and percentages. Yearly prevalence trends of *Enterococcus* spp. were evaluated descriptively and illustrated graphically.

Comparisons between *Enterococcus*-positive and non-*Enterococcus* patients were performed using the Chi-square test or Fisher's exact test for categorical variables, as appropriate. Associations between infection source, comorbidities, vancomycin resistance, and clinical outcomes were assessed using the same statistical methods.

When applicable, odds ratios (ORs) with 95% confidence intervals (CIs) were calculated to estimate the strength of associations. A p-value < 0.05 was considered statistically significant.

3. Results

3.1. Socio-demographic and Clinical Characteristics

A total of 1,352 patients with confirmed wound infections were included. The mean age was 58.3 ± 22.18 years, with a slight male predominance (56.7%). Nearly half of infections were hospital-acquired (49.6%), while 50.4% were community-acquired. The mean length of hospital stay was 23.9 ± 35.2 days. Overall mortality was 13.9%.

Comorbidities were highly prevalent, particularly hypertension (47.7%) and diabetes mellitus (37.5%). Other notable conditions included coronary artery disease (22.9%), cerebrovascular accidents (9.5%), chronic kidney disease (9%), and cancer (7.9%). Prior antibiotic exposure before surgery was reported in 48.2% of patients (Table 1)

Table 1
Demographic and Clinical Characteristics of the study population (n = 1352)

Variable	Category	Frequency (n)	Percentage (%)
Age	Mean $\pm$ SD (years)	58.3 $\pm$ 22.18	—
Gender	Male	767	56.7
	Female	585	43.3
Infection Source	Hospital-acquired (HA)	670	49.6
	Community-acquired (CA)	682	50.4
Hospital Stay	Mean $\pm$ SD (days)	23.9 $\pm$ 35.2	—
Outcome	Discharged	1164	86.1
	Died	188	13.9
Comorbidities	Hypertension	645	47.7
	Diabetes mellitus	507	37.5
	Coronary artery disease	309	22.9
	Cerebrovascular accident (CVA)	128	9.5
	Chronic kidney disease	123	9.0
	Cancer	107	7.9
	Alzheimer's disease	42	3.1
	Paraplegia	35	2.6
	Chronic obstructive pulmonary disease (COPD)	33	2.4
	Atrial fibrillation	25	1.9
	Peripheral artery disease (PAD)	25	1.8
	Parkinson's disease	11	0.8
	Hypothyroidism	10	0.7
	Hyperthyroidism	2	0.1
	Others*	112	9.8
Antibiotic Use Before Surgery	Yes	652	48.2
	No	700	51.8

Footnote

Others include autoimmune diseases, asthma, chronic heart failure, dyslipidemia, epilepsy, familial Mediterranean fever (FMF), hepatitis C, osteoporosis, and thalassemia.

3.2. Microbiological Profile of Wound Infections

A total of 1,352 microbial isolates were identified. Gram-negative organisms predominated, with *Escherichia spp.* (24.3%) and *Pseudomonas spp.* (18.3%) being the most frequent. *Enterococcus spp.* represented 10.8% of isolates, ranking third overall, followed by *Staphylococcus spp.* (9.5%).

Other pathogens included *Acinetobacter spp.* (8.4%), *Proteus spp.* (8.3%), and *Klebsiella spp.* (8.1%), while less common isolates included *Enterobacter spp.* (4.2%) and *Candida spp.* (2.0%) (Table 2).

Enterococcus spp. ranked among the leading pathogens, highlighting their clinical relevance in wound infections.

Table 2 Prevalence of Pathogens		
Pathogen	n	%
<i>Escherichia spp.</i>	328	24.3
<i>Pseudomonas spp.</i>	247	18.3
<i>Enterococcus spp.</i>	146	10.8
<i>Staphylococcus spp.</i>	129	9.5
<i>Acinetobacter spp.</i>	113	8.4
<i>Proteus spp.</i>	112	8.3
<i>Klebsiella spp.</i>	110	8.1
<i>Enterobacter spp.</i>	57	4.2
<i>Candida spp.</i>	27	2.0
Others	108	7.9
Total	1352	100.0

3.3. Trends in *Enterococcus* Prevalence

A clear upward trend in the prevalence of *Enterococcus spp.* was observed over the study period. The proportion increased from approximately 4% in 2018 to a peak of 16% in 2021, followed by a decline to 10% in 2022 (Fig. 1).

This pattern indicates a temporal shift in the microbiological profile of wound infections, with increasing involvement of *Enterococcus* spp. over time.

3.4. Characteristics of the *Enterococcus* Population

The *Enterococcus* subgroup included 146 patients (10.8%), with a mean age of 59.3 ± 18.79 years and a slight male predominance (54.1%). Most infections were hospital-acquired (69.9%), and the mean hospital stay was 25.4 ± 33.88 days.

Clinical outcomes showed a mortality rate of 19.9%, higher than that observed in the overall cohort. Comorbidities were common, particularly hypertension (52.7%) and diabetes mellitus (52.1%), followed by coronary artery disease (26.7%), cancer (15.8%), and chronic kidney disease (15.1%). Prior antibiotic use was reported in 67.1% of cases.

The prevalence of vancomycin-resistant *Enterococcus* (VRE) was 21.9% (Table 3).

The *Enterococcus* population is characterized by high comorbidity burden, frequent antibiotic exposure, and increased mortality.

Table 3
Characteristics of the Enterococcus Population (n = 146)

Variable	Category	n	%
Age	Mean $\pm$ SD	59.3 $\pm$ 18.79	—
Gender	Male	79	54.1
	Female	67	45.9
Infection Source	Hospital-acquired (HA)	102	69.9
	Community-acquired (CA)	44	30.1
Hospital Stay	Mean $\pm$ SD	25.4 $\pm$ 33.88	—
Outcome	Discharged	117	80.1
	Died	29	19.9
Comorbidities	Hypertension	77	52.7
	Diabetes mellitus	76	52.1
	Coronary artery disease	39	26.7
	Cancer	23	15.8
	Chronic kidney disease	22	15.1
	CVA	17	11.6
	PAD	10	6.8
	Alzheimer's	7	4.8
	Hypothyroidism	4	2.7
	COPD	2	1.4
	Others*	35	24
Antibiotic use	Yes	98	67.1
	No	48	32.9
VRE	Yes	32	21.9
	No	114	78.1

Footnote

Others include autoimmune diseases, asthma, chronic heart failure, dyslipidemia, epilepsy, familial Mediterranean fever (FMF), hepatitis C, osteoporosis, and thalassemia.

3.5. Comparative Analysis of *Enterococcus*-Positive and Non-*Enterococcus* Patients

No significant differences were observed between *Enterococcus*-positive and non-*Enterococcus* patients in terms of age, gender distribution, or length of hospital stay (all $p > 0.05$).

However, infection source differed significantly between the two groups, with *Enterococcus* infections being more frequently hospital-acquired compared to non-*Enterococcus* infections (69.8% vs. 47.1%, $p < 0.001$).

Clinical outcomes also varied, as mortality was significantly higher among *Enterococcus*-positive patients (19.9% vs. 13.2%, $p = 0.028$). In addition, prior antibiotic exposure before surgery was more common in the *Enterococcus* group (67.1% vs. 45.9%, $p < 0.001$).

Regarding comorbidities, *Enterococcus* infections were significantly associated with diabetes mellitus (52.0% vs. 35.7%, $p < 0.001$), chronic kidney disease (15.1% vs. 8.4%, $p = 0.008$), and cancer (15.8% vs. 7.0%, $p < 0.001$). In contrast, hypertension, coronary artery disease, chronic obstructive pulmonary disease, and cerebrovascular accidents were not significantly associated with *Enterococcus* infections.

Enterococcus-positive patients were more likely to have hospital-acquired infections, prior antibiotic exposure, and a higher burden of comorbidities, and experienced worse clinical outcomes (Table 4).

Table 4
Comparative Characteristics of Enterococcus-Positive and Non-Enterococcus Patients

Variable	Category	Enterococcus (n = 146)	Non-Enterococcus (n = 1206)	p-value
Gender	Male	79 (54.1%)	688 (57.0%)	0.499
	Female	67 (45.9%)	518 (43.0%)	—
Age (years)	Mean ± SD	59.3 ± 18.79	58.2 ± 22.56	0.513
Hospital stay (days)	Mean ± SD	25.49 ± 33.88	23.73 ± 35.42	0.569
Infection source	Hospital-acquired (HA)	102 (69.8%)	568 (47.1%)	< 0.001
	Community-acquired (CA)	44 (30.2%)	638 (52.9%)	—
Outcome	Discharged	117 (80.1%)	1047 (86.8%)	0.028
	Died	29 (19.9%)	159 (13.2%)	—
Antibiotic use before surgery	Yes	98 (67.1%)	554 (45.9%)	< 0.001
	No	48 (32.9%)	652 (54.1%)	—
Diabetes mellitus	Yes	76 (52.0%)	431 (35.7%)	< 0.001
	No	70 (48.0%)	775 (64.3%)	—
Hypertension	Yes	77 (52.7%)	568 (47.1%)	0.179
	No	69 (47.3%)	638 (52.9%)	—
Coronary artery disease	Yes	39 (26.7%)	270 (22.4%)	0.240
	No	107 (73.3%)	936 (77.6%)	—
COPD	Yes	2 (1.4%)	31 (2.6%)	0.570*
	No	144 (98.6%)	1175 (97.4%)	—
Chronic kidney disease	Yes	22 (15.1%)	101 (8.4%)	0.008
	No	124 (84.9%)	1105 (91.6%)	—
Cerebrovascular accident	Yes	17 (11.6%)	111 (9.2%)	0.342
	No	129 (88.4%)	1095 (90.8%)	—
Cancer	Yes	23 (15.8%)	84 (7.0%)	< 0.001
	No	123 (84.2%)	1122 (93.0%)	—

Variable	Category	Enterococcus (n = 146)	Non-Enterococcus (n = 1206)	p-value
Other comorbidities	Yes	59 (40.4%)	230 (19.1%)	< 0.001
	No	87 (59.6%)	976 (80.9%)	—

Footnote

* Fisher's exact test was used where appropriate.

3.6. Distribution of *Enterococcus* Species and Vancomycin Resistance

The distribution of *Enterococcus* species isolated from wound infections showed that *Enterococcus faecalis* was the predominant species, accounting for 77% of isolates, while *Enterococcus faecium* represented 23% (Fig. 2).

Vancomycin resistance varies markedly between species. Among *E. faecalis* isolates, 5.9% were classified as vancomycin-resistant *Enterococcus* (VRE), whereas 94.1% were non-resistant. In contrast, a substantially higher resistance rate was observed in *E. faecium*, with 40% of isolates identified as VRE and 60% as non-resistant (Fig. 3).

E. faecium demonstrates a substantially higher resistance burden compared to *E. faecalis*.

3.7. Association Between Infection Source and Mortality

In the overall population, mortality was significantly associated with infection source ($p < 0.001$), with hospital-acquired infections contributing disproportionately to deaths. In contrast, no significant association between infection source and mortality was observed within the *Enterococcus* subgroup. However, hypertension ($p = 0.018$) and chronic kidney disease ($p = 0.035$) were significantly associated with mortality in this group (Table 5).

Table 5
Association Between Infection Source, Comorbidities, and Mortality

Variable	Category	Discharged (n = 1164)	Died (n = 188)	p-value
Infection source (overall)	Community-acquired	621 (53.4%)	61 (32.4%)	< 0.001
	Hospital-acquired	543 (46.6%)	127 (67.6%)	—
Infection source (<i>Enterococcus</i>)	Community-acquired	37 (31.6%)	7 (24.1%)	0.432
	Hospital-acquired	80 (68.4%)	22 (75.9%)	—
Diabetes mellitus	Yes	58 (49.6%)	18 (62.0%)	0.228
	No	59 (50.4%)	11 (38.0%)	—
Hypertension	Yes	56 (47.8%)	21 (72.4%)	0.018
	No	61 (52.2%)	8 (27.6%)	—
Coronary artery disease	Yes	30 (25.7%)	9 (31.0%)	0.557
	No	87 (74.3%)	20 (69.0%)	—
COPD	Yes	2 (1.7%)	0 (0.0%)	1.000*
	No	115 (98.3%)	29 (100%)	—
Chronic kidney disease	Yes	14 (12.0%)	8 (27.6%)	0.035
	No	103 (88.0%)	21 (72.4%)	—
Cerebrovascular accident	Yes	13 (11.1%)	4 (13.8%)	0.747*
	No	104 (88.9%)	25 (86.2%)	—
Cancer	Yes	18 (15.4%)	5 (17.2%)	0.806
	No	99 (84.6%)	24 (82.8%)	—
Other comorbidities	Yes	45 (38.5%)	14 (48.3%)	0.335
	No	72 (61.5%)	15 (51.7%)	—
Footnote				

* Fisher's exact test was used where appropriate.

3.8. Impact of VRE on Clinical Outcomes

The mortality rate was higher among VRE cases compared to non-VRE cases (25.0% vs. 18.4%); however, this difference was not statistically significant.

Regarding infection type, patients with hospital-acquired infections had higher odds of VRE compared to those with community-acquired infections (OR = 2.17, 95% CI: 0.82–5.71), although this association did not reach statistical significance. Prior antibiotic use before surgery was more frequently reported among VRE patients than non-VRE patients (78.1% vs. 64.0%).

The only statistically significant difference observed was in hospital stay duration. VRE patients had a mean hospital stay of 25.38 ± 36.5 days, compared to 25.52 ± 33.28 days in non-VRE patients (p = 0.021), although the difference in mean values was minimal (Table 6).

Although not statistically significant, VRE cases tend to be associated with worse clinical profiles.

Table 6
Association of VRE Status with Clinical Outcomes and Infection Characteristics

Variable	Category	VRE (n = 32)	Non-VRE (n = 114)	p-value
Mortality	Yes	8 (25.0%)	21 (18.4%)	0.410
	No	24 (75.0%)	93 (81.6%)	—
Infection source	Community-acquired	6 (18.8%)	38 (33.3%)	0.112
	Hospital-acquired	26 (81.2%)	76 (66.7%)	—
Antibiotic use before surgery	Yes	25 (78.1%)	73 (64.0%)	0.134
	No	7 (21.9%)	41 (36.0%)	—
Hospital stays (days)	Mean ± SD	25.38 ± 36.50	25.52 ± 33.28	0.021

Discussion

This study highlights the emerging role of *Enterococcus* spp. as clinically significant pathogens in wound infections, particularly in hospital settings, while providing important insights into their resistance profiles and associated risk factors.

Wound infections acquired during hospitalization occur at a rate comparable to community-acquired infections (49.6% vs. 50.4%). Community-acquired infections are defined as those acquired outside healthcare settings. Healthcare-associated postoperative surgical site infections (SSIs), which account for a substantial proportion of wound infections, have been reported by the WHO to occur in approximately 23% of surgical procedures annually. [19]. Notably, surgical site infections are recognized as a major contributor to healthcare-associated infections[20].

Regarding the isolated pathogens, Gram-negative bacteria predominated, with *Escherichia coli* being the most frequently detected pathogen, followed by *Pseudomonas spp.* This observation aligns with previous reports demonstrating the increasing dominance of Gram-negative organisms in wound and surgical site infections. [21–23]. In addition, *Escherichia coli* has been identified as the most common Gram-negative pathogen in wound infections across multiple reports [22–24].

Alternatively, *Enterococcus spp.* accounted for 10.8% of isolates and were recovered more frequently than *S. aureus* (9.5%). This finding highlights the growing clinical relevance of enterococci in wound infections, particularly in hospital settings. While *S. aureus* is traditionally reported as the most commonly isolated Gram-positive pathogen, several studies have shown that the prevalence of *Enterococcus spp.* may be comparable to our finding [25] or lower [21, 23].

Additionally, *Candida spp.* was isolated in a small proportion of cases (2%). This finding is consistent with other reports, where *Candida* species have been recognized as causative agents in wound infections, particularly in healthcare settings and more commonly among critically ill patients and those admitted to intensive care units [23, 26].

A central finding of this study is the clear increase in the prevalence of *Enterococcus spp.* over the study period, with a peak observed in 2021 (16%). This upward trend suggests a shift in the epidemiology of wound infections toward greater involvement of *Enterococci*. This trend may be partially explained by the impact of the COVID-19 pandemic, which was associated with increased hospitalization rates, prolonged intensive care stays, and widespread antibiotic use. These factors are known to promote the emergence and spread of opportunistic and resistant pathogens, including *Enterococci* [27, 28]. In Lebanon, COVID-19 cases increased significantly during this period, with peaks occurring in late 2020 and early 2021 accompanied by a comparable rise in mortality [29–31]. A parallel rise in *Enterococcus spp.* infections during the COVID-19 pandemic years has also been reported in other studies [32]. However, these reports more commonly described bacteremia rather than wound infections, particularly among critically ill patients [32, 33].

Most enterococcal infections in this study were hospital-acquired, supporting the well-established role of enterococci—particularly *Enterococcus faecalis* and *Enterococcus faecium*—as common pathogens in hospital-acquired infections [16, 34]. Moreover, among nosocomial wound infections, *Enterococcus spp.* is frequently identified as important causative agents of postoperative surgical site infections [16, 35, 36]. This can be attributed to their ability to survive in hospital environments and persist on medical equipment, thereby facilitating their transmission. In addition, their capacity to form biofilms promotes persistence in chronic wounds and reduces susceptibility to antimicrobial therapy. Furthermore, antibiotics are often ineffective in chronic wound infections, and their overuse contributes significantly to the global burden of antimicrobial resistance [37].

Patients with enterococcal infections exhibited a significantly higher mortality rate (19%) compared with those infected with other pathogens. This finding underscores the clinical severity of enterococcal infections and their association with adverse outcomes. The predominance of hospital-acquired

infections and the presence of multiple comorbidities likely contribute to this increased mortality. This is in line with previous reports indicating that hospital-acquired enterococcal infections contribute significantly to patient mortality and are associated with considerable morbidity [34].

Patients with wound infections had multiple comorbidities, most commonly hypertension (47.7%), diabetes mellitus (37.5%), coronary artery disease (22.9%), chronic kidney disease (9%), cerebrovascular accidents (9.5%), and cancer (7.9%).

With regard to *Enterococcus* infections, diabetes mellitus was significantly associated with enterococcal wound infections. Impaired wound healing in patients with diabetes increases susceptibility to wound infections and is recognized as an important risk factor for both wound and surgical site infections [38–40]. In addition, diabetes mellitus has been identified as an independent risk factor for enterococcal infection [41] and *Enterococcus* species are well-documented causative pathogens in diabetic foot infections [42, 43]. Similarly, chronic kidney disease and cancer were significantly associated with enterococcal infections, likely reflecting the immunocompromised status of these patient populations. This finding is consistent with previous reports indicating that immunocompromised patients are at greater risk for *Enterococcus* infections [44].

This supports existing evidence that previous antibiotic use increases the risk of colonization and infection, and is considered a major risk factor for their development [18, 36, 45].”

Prior antibiotic exposure was significantly more frequent among patients with enterococcal infections. This finding supports existing evidence that previous antibiotic use increases the risk of colonization and infection, and is considered a major risk factor for their development [16, 35, 44]. It also highlights the critical importance of antimicrobial stewardship programs to limit unnecessary antibiotic use and reduce the emergence of resistant strains.

Regarding *Enterococcus* species distribution, evaluation of enterococcal wound infections revealed that *Enterococcus faecalis* was the predominant species, representing 77% of isolates, while *Enterococcus faecium* accounted for 23% of cases. This finding is consistent with previous studies in which *Enterococcus faecalis* was reported as the most frequently isolated enterococcal species [23, 25, 45]. However, other reports have found *Enterococcus faecium* to be the more prevalent species in certain settings. [16].

Additionally, vancomycin-resistant *Enterococci* (VRE) represented 21.9% of all isolated *Enterococcus* species. Data on VRE prevalence in Lebanon are limited. A study conducted between 2013 and 2018 reported an increase in VRE cases from 0.6% in 2013 to 5.9% in 2018 [46]. In contrast, a study published in 2001 reported no VRE isolates [45]. Compared with both our findings and more recent Lebanese reports, this trend underscores the progressive emergence and increasing spread of vancomycin resistance among *Enterococcus* species. However, *Enterococcus faecium* demonstrated a markedly higher rate of vancomycin resistance compared with *Enterococcus faecalis*. This finding is consistent with previous studies showing higher VRE rates among *Enterococcus faecium* isolates [23], although

even greater rates of vancomycin-resistant *Enterococcus faecalis* have been reported in other settings [16]. The presence of vancomycin-resistant enterococci remains a significant concern due to limited therapeutic options and the potential for hospital outbreaks [16]. Several factors have been attributed to the increasing rate of multiple antimicrobial resistance (AMR) mechanisms, particularly inappropriate antimicrobial use, water contamination, and the refugee crisis in Lebanon [47].

In line with these findings, our data showed a higher mortality rate among patients with VRE wound infections. Previous studies have similarly reported that VRE infections are associated with increased complications and higher mortality compared with vancomycin-sensitive enterococcal infections. [35, 41]. Although this difference did not reach statistical significance, it may be attributed to the relatively small number of VRE cases included in the study. Nevertheless, the observed trend suggests that VRE infections may be associated with a more severe clinical profile, particularly among patients with hospital-acquired infections and prior antibiotic exposure.

Antimicrobial resistance (AMR) remains one of the largest health problems worldwide. This problem was highly related to several causes, mainly with the excessive use and/or the misuse of Antibiotics during COVID-19 pandemic which has greatly increase the prevalence of AMR worldwide [48, 49] Therefore, new strategies to fight this problem are a must. Several strategies are now applied in research laboratories to find solutions against AMR, these strategies are very wide, starting by the use of the “Trojan Horse Technique” to introduce antibiotics inside bacterial cell by a very smart technique[50]. On the other hand, targeting new bacterial ultra-structures is among these techniques, such as targeting bacterial “Metallophores” that play an importance role in bacterial virulence, and targeting these structures can decrease bacterial virulence[51]. Also, the use of bacteriophages to fight Multi-Drug Resistant (MDR) strains is among these strategies, it is known as “Antimicrobial Phages” [52, 53]. These techniques can also be applied to AMR in *Enterococcus spp.* such as the case of VRE.

Limitations

Several limitations should be acknowledged. The retrospective design and single-center setting may limit the generalizability of the findings. In addition, the absence of molecular characterization of resistance mechanisms that is more and more used in recent studies to determine the main antimicrobial resistance genes [54, 55]. And the lack of standardized severity scoring systems may restrict deeper understanding of infection dynamics. Future multicenter studies incorporating molecular approaches are warranted to further elucidate the epidemiology and resistance patterns of *Enterococcus spp.* in wound infections.

Conclusion

This study provides important epidemiological data on *Enterococcus*-associated wound infections in Lebanon, contributing to the limited literature from the Middle East. The findings highlight the increasing prevalence of *Enterococcus spp.* their role as emerging nosocomial pathogens, and their association

with antimicrobial resistance and adverse clinical outcomes. Together, these observations underscore the need for continuous surveillance, strengthened infection control measures, and effective antimicrobial stewardship strategies to limit the spread of resistant organisms.

Declarations

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Author Contribution

SMS, MF, ZE, GG and TC contributed to the project design and analysis of results. SMS, FAZMO, MF, ZE, GG and TC contributed to writing of manuscript. SMS and GG contributed to the study conception, study design, proposal development, oversight of data collection. FAZMO, RK, AA and KK contributed to data collection and data entry, TC and GG contributed to data entry, data review, data analysis, interpretation, and review of manuscript drafts, SMS, MF, ZE, GG and TC contributed to revision and approval of final versions submitted for publication. All authors critically revised and edited the manuscript, and approved the final draft.

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Figures

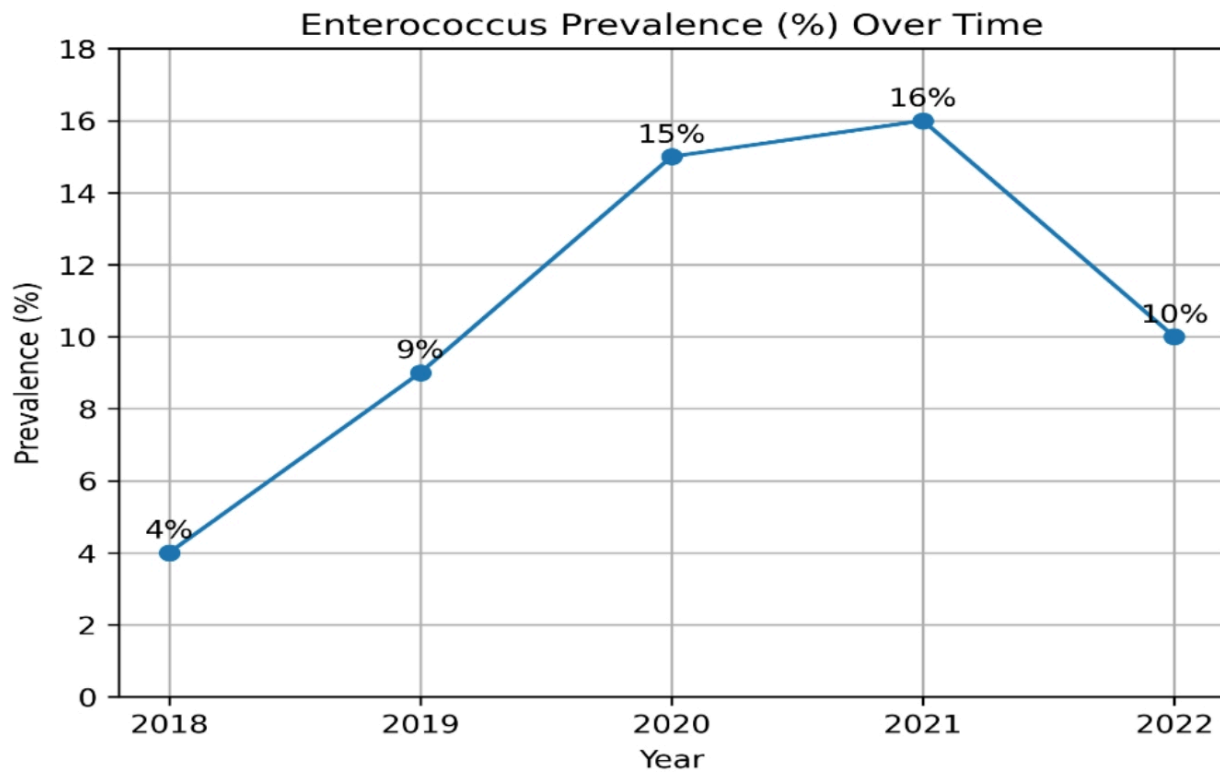


Figure 1

Trends in the prevalence of *Enterococcus* spp. in wound infections from 2018 to 2022.

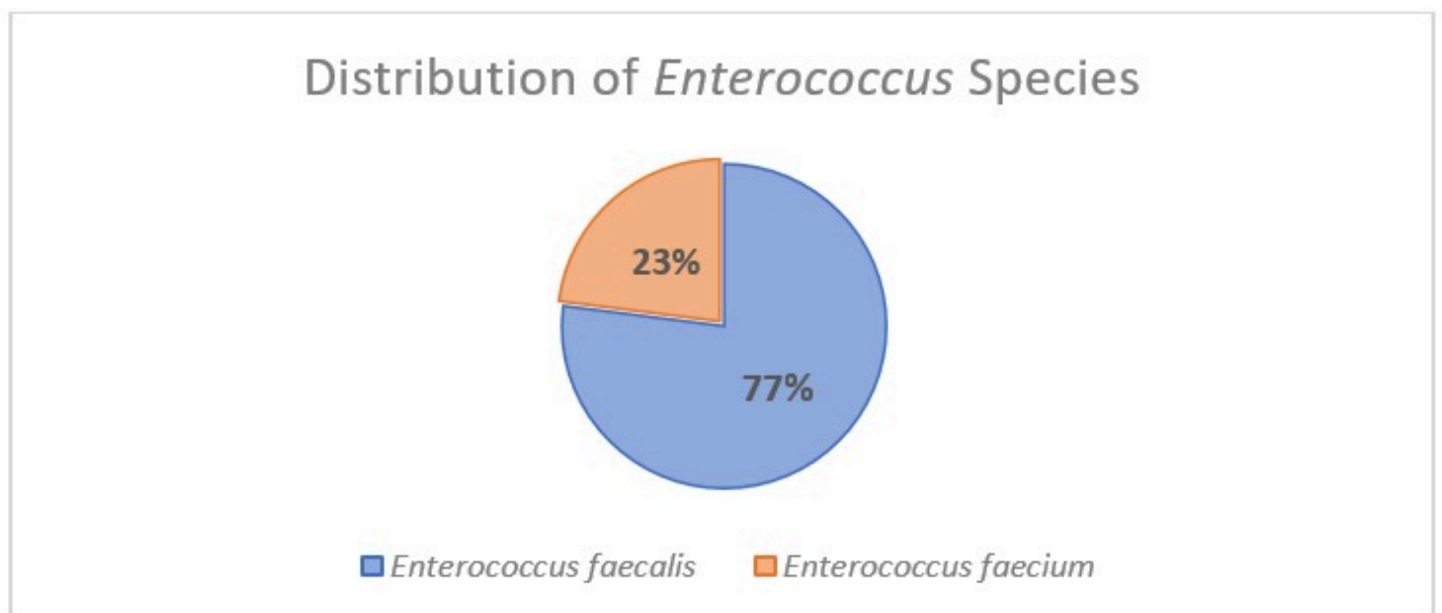


Figure 2

Distribution of *Enterococcus* species isolated from wound infections.

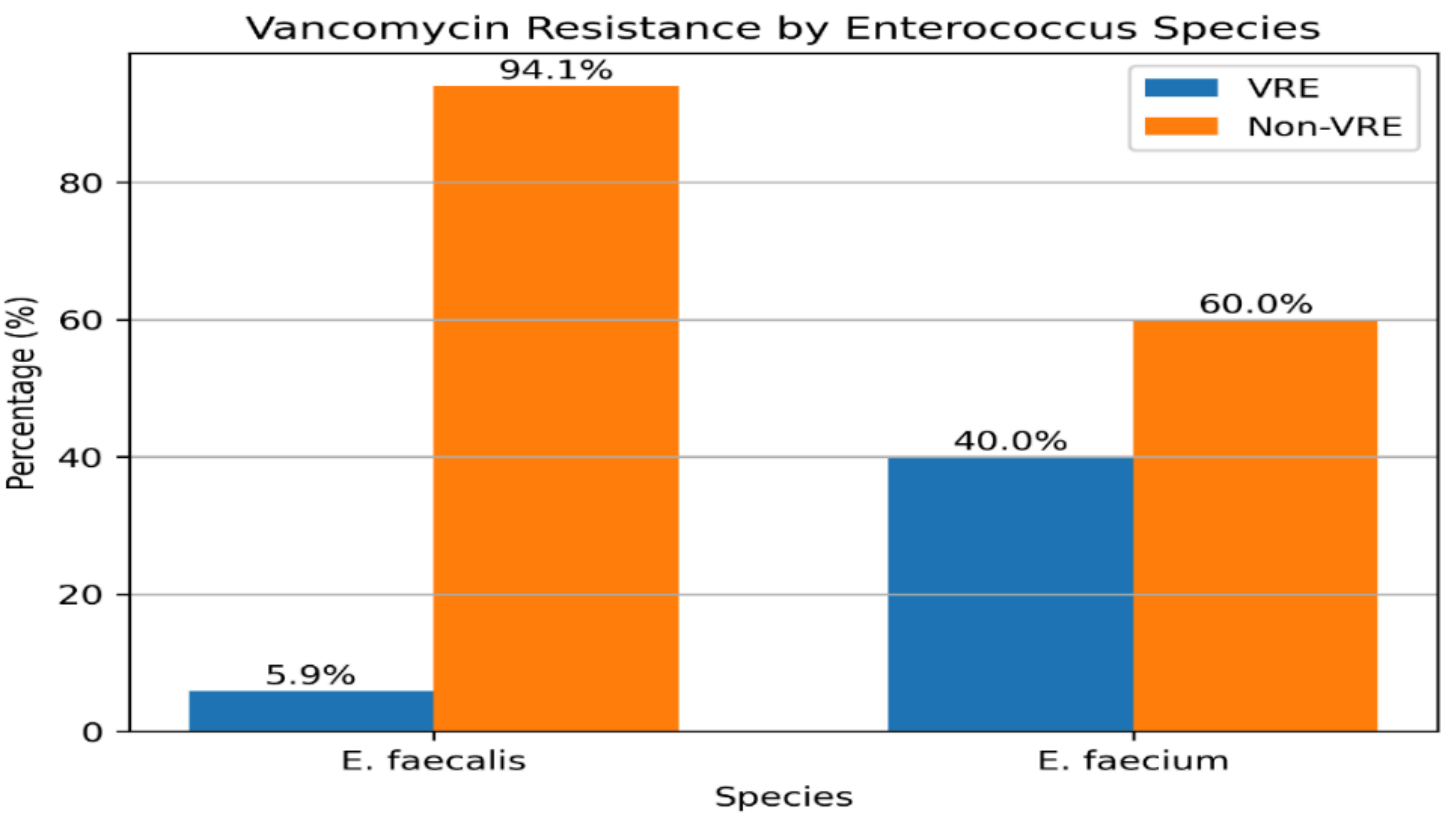


Figure 3

Comparison of vancomycin resistance rates between *Enterococcus faecalis* and *Enterococcus faecium*.