ORIGINAL ARTICLE

CONTENTS

Healthcare-associated infections after maxillofacial and oral surgery procedures in patients with combat-related head and neck injuries in Ukraine: Results of a multicenter study (2022-2025)

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ABSTRACT

Aim: To estimate the prevalence and risk-factor of HAI after maxillofacial and oral surgery procedures in patients with combat-related head and neck injuries in Ukraine, and determine antimicrobial resistance of the responsible pathogens.

Materials and Methods: A multicenter prospective observational cohort study was conducted from June 2022 to December 2025. Definitions of HAIs were adapted from the CDC/NHSN. Antibiotic susceptibility test of bacteria was determined according to the EUCAST.

Results: Among 2,631 patients, 1,075 (40.9%) HAIs were observed. The most frequently reported HAIs were surgical site infections (54%), bone and joint infection (14.2%), pneumonia (12.2%), urinary tract infections (8.6%), bloodstream infections (6.6%), Eye, ear, nose, throat, or mouth infection (4.4%). Risk factor for HAIs were length of stay in ICU, type of injury, intubation, vascular and urinary catheters. The most pathogens isolated from HAIs were *Escherichia coli* (19.2%), *Pseudomonas aeruginosa* (7.6%), *Klebsiella pneumonia* (7.3%), *Enterococcus faecalis* (6.9%), *Acinetobacter baumannii* (6.6%), *Staphylococcus aureus* (5.5%), *Serratia marcescens* (5.5%). Meticillin resistance was reported in 36.1% of S. aureus, and 15.9% of enterococci were resistant to vancomycin. Resistance to third-generation cephalosporins was reported in 64.8% *K. pneumoniae* and in 43.6% *E. coli*.

Conclusions: This study found a high prevalence of HAIs in patients with combat-related head and neck injuries who has undergone maxillofacial or/and oral surgery procedures, caused by MDROs, varying depending on the bacterial species, and antimicrobial group.

KEYWORDS: military conflict, combat-related head and neck injuries, maxillofacial and oral surgery, healthcare-associated infections, risk factors, multidrug-resistant organisms, Ukraine

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INTRODUCTION

The protracted military conflict in Eastern areas of Ukraine, beginning in February 2022, has strained the medical capacity of Ukraine's health system during a period of mass casualty and severe injury among both civilians and military combatants [1]. Combat-related injuries in Ukraine are characterized by a high prevalence of complex polytrauma driven by artillery, drones, and mines [2]. These often include bone and soft tissue injuries in head and neck, frequently resulting in multiple, simultaneous injuries rather than isolated trauma. [3].

Infectious complications following surgical treatment for patients with combat -related injuries and wounds are serious problem for health-care system of Ukraine. These infections reduce the effectiveness of treatment and increase the duration of hospitalization and the cost of treatment [3]. Despite of advances have been made in infection control practices and availability of antimicrobial prophylaxis; HAIs remain a substantial cause of morbidity [4]. According to published studies, pooled healthcare-associated infection (HAI) rates after maxillofacial and oral surgery procedures ranged from 0% to 62% depending on surgery type [5].

HAIs are one of the most common adverse events following surgical maxillofacial and oral procedures in patients with combat injuries and wounds. According to the literature, HAIs following surgical treatment (maxillofacial and oral procedures) of patients with combat injuries and wounds are high, with a significant 30.2% incidence in head and neck trauma cases [6]. These infections are commonly linked to mine-explosive (25.1%) and gunshot wounds (10.7%), with complications including cellulitis, abscesses, and deep space infections, requiring prompt antimicrobial intervention [6]. Despite the availability of new methods for diagnosing and treating patients, as well as the use of new technologies for infection control, the number of HAIs in patients with combat-related injuries and wounds is not decreasing.

The World Health Organization estimates that HAI caused by multi-drug-resistant organisms (MDROs) is the most frequently occurring adverse event for most country in world [7]. Many countries, including Ukraine have developed and implemented national strategies for the control and prevention of HAIs [8]. However, how this has affected the prevalence of HAIs in patients with combat-related injuries and wounds and the increasing emergence and spread of MDROs is unknown.

In Ukraine the incidence and prevalence of HAIs and antimicrobial resistance of the responsible pathogens in patients with combat-related injuries has rarely been published. A previous study has focused on the prevalence of HAIs among civilian populations and antimicrobial resistance of the responsible pathogens in Ukraine [4, 9]. These studies have found that contamination of environmental surfaces in hospital rooms serves as a reservoir for transmission of MDROs to patients, leading to colonization or/and infection [8, 10-12]. However, these results do not provide sufficient information about to the spread of the incidence of HAIs caused by MDROs in with combat injuries and wounds after maxillofacial and oral surgical procedures, which requires further study. Also, in literature, there is no study estimating the incidence rates of HAIs in patients with combat related head and neck injuries, as well as there is limited information on the AMR of the responsible pathogens and potential risk factors for HAIs associated with maxillofacial and oral surgery procedures.

AIM

The aim of this study was to estimate the prevalence and risk factor of HAI after maxillofacial and oral surgery procedures in patients with combat-related head and neck injuries in Ukraine, and determine antimicrobial resistance (AMR) of the responsible pathogens.

MATERIALS AND METHODS

DESIGN, SETTING AND PATIENTS

A multicenter prospective observational cohort study based on HAIs surveillance data was conducted from 28st June, 2022 to 31st December 2025. This study was performed in eight civilian hospitals which are located in six regions (Kharkiv, Dnipro, Kherson, Zaporizhzhia, Odessa, and Kyiv) of Ukraine. The median number of beds in each participating hospital was 650 beds, and the number of beds in intensive care units (ICUs) ranged from 10 to 12. Overall bed occupancy was 100% in each department of surgery and the ICUs. All participating hospitals are similar in terms of medical equipment, personnel and clinical microbiology laboratory with the capacity to process cultures. These hospitals had at least one full-time hospital epidemiologist or infection control professional and a data manager.

The study included patients with combat related head and neck injuries, aged 24-56 years who has undergone maxillofacial or/and oral surgery procedures and who stayed for more than 48 h in the surgical departments and ICUs, and survived at least 7 days after surgery. A total of 2,631 patients fulfilled the requirements of inclusion criteria were included in the study. Of which 2,584 (98.2%) were military combatants and 47 (1.8%) were civilians that has combat trauma or injured in military conflict area. Patients who passed away within 48 hours after the operation, maxillofacial or/and oral surgery procedures performed for wound infection complication and patients that had injuries and wounds in head and neck outside of the active war theaters were excluded.

DEFINITIONS

Specific HAI site definitions were adapted from the Centers for Disease Control and Prevention's (CDC's) 2008 National Healthcare Safety Network (NHSN) case definitions [13]. In this study an HAI cases was defined as an infection arising >48 h. after maxillofacial or/ and oral surgery and other medical procedures in hospital, and not present or incubating on admission, unless the patient had been discharged from hospital within a defined period. An incident HAI was defined by microbiologically confirmed CDC/NHSN HAI epidemiological case definitions. Institution of antibiotics by a physician without microbiological confirmation was not considered to be sufficient for diagnosis of an HAI because of widespread use of antimicrobial drugs for infection prevention in surgery and ICUs of hospitals in Ukraine [8]. Serologic and antigen test results were not included in case definitions. An HAI cases was deemed to be ICU-acquired where it occurred on or after the third calendar day in the ICU. Multi-drug resistance was defined in accordance with current published interim standard definitions [14]. Cases were described as community acquired if MDROs were isolated from patients on either of the first two days of hospital admission.

ETHICS

The study protocol complies with the ethical principles of the Helsinki Declaration and approval of the Ethics Committee of the Ukrainian Association of Infection Control and Antimicrobial Resistance (Protocol No. 3 dated 17.03.2022). Participants' data were anonymized prior to the analysis. According to the Act of Ukraine, surveys and evaluations that are intended to ensure that diagnosis and treatment produce the intended results do not require patient consent.

DATA COLLECTION

Surveillance data on all HAI cases, both in patients and their causative pathogens, were collected on a form specifically designed by the investigators using medical records comprising charts, daily flow sheets, and laboratory (microbiology) results. The collected data included demographics, Injury type/ethiology, time from the moment of injury to the first specialized medical help, surgical interventions on the previous evacuation stages, presence of a tracheostomy, trauma-associated complications, concomitant damage to other organs and systems, presence of concomitant somatic pathologies, type of concomitant somatic pathologies, harmful habits, location of soft tissue wounds of the head, burns, facial fractures, type of fractures (mandible body, mandible symphysis, mandible ramus, Le For I, Le For II, Le For III, zygoma, naso-orbito-ethmoid complex, orbit, nose, frontal sinus), dimensions of the soft tissue defect, dimensions of the bone defect, presence and the character of the foreign body, character of the dento-alveolar trauma, concomitant head and neck injuries, masticatory deficiency, visual functions, vascular and urinary catheter, endotracheal intubation, type of HAI, date of infection onset, clinical signs, administered antibiotics, isolated pathogens with antibiogram results, and outcome on discharge from the hospitals. The risk factors were evaluated from the time of admission until the onset of HAI.

MICROBIOLOGICAL METHODS

All sample isolates from HAI cases were sent to the local microbiology laboratory. Microbial isolates were identified and antimicrobial susceptibilities were determined using an automated microbiology system (Vitek-2 Compact; bioMe´rieux, Marcy l'Etoile, France). Antibiotic susceptibility testing of bacteria was determined according to the protocol of the European Committee on Antimicrobial Susceptibility Testing (EUCAST) (http://eucast.org). Multi-drug resistance (MDR) for *Acinetobacter* spp. and *Pseudomonas aeruginosa* was defined in accordance with published definitions, which were used in NHSN Antimicrobial Resistance (AMR) report [15]. MDR for *Klebsiella pneumoniae* and *Escherichia coli* was defined as being non-susceptible to at least one drug in three antimicrobial agents/groups [16].

STATISTICAL ANALYSIS

HAIs after maxillofacial and oral surgery procedures in patients with combat related head and neck injuries were analyzed as a binary exposure variable (no HAI, any HAI). Statistical data analysis was performed using Microsoft Excel for Windows (Microsoft Corp, Redmond, WA). Results are expressed as median (range), mean ± standard deviation for continuous variables, and the number with the corresponding percentage for qualitative variables. A descriptive analysis was performed by calculating the number and percentage for each value. Pearson's chi-square test was performed to check the matching performance between the case and comparison groups and compare the differences between groups for categorical variables. Multivariate analysis was carried out using stepwise logistic regressions to assess the predictive factors of the HAIs after maxillofacial and oral surgery procedures. In this study, statistical significance was defined as $P < 0.05$.

AI STATEMENT

The author states that no AI tools were used in writing this article.

RESULTS

PREVALENCE OF HAIS

During the study period (2022-2025), 1,075 of 2631 patients with combat-related head and neck injuries after maxillofacial and oral surgery procedures were found to have HAIs. The prevalence of this patients with at least one HAI was 40.9% [95% confidence interval (CI) 39.9-41.9]. In this study ninety-seven percent of patients who has undergone maxillofacial or/and oral surgery procedures with an HAI were receiving at least one antimicrobial on the day of the survey. The most frequent types of HAI in patients with combat-related head and neck injuries after maxillofacial and oral surgery procedures were surgical site infections (SSIs) (54%), bone and joint infection (osteomyelitis) (14.2%), pneumonia (PNEU) (12.2%), Urinary tract infections (UTIs) (8.6%), bloodstream infections (BSIs) (6.6%), and eye, ear, nose, throat, or mouth (EENT) infection (4,4%) (Table 1).

CHARACTERISTICS OF COMBAT-RELATED HEAD AND NECK INJURIES

Among patients with HAI a mild combat-related head and neck injuries was diagnosed in 4.7% (114/2631) of the wounded, severe – in 71.8% (1746/2631), extremely severe – in 23.5% (571/2631). The cause of combat-related head and neck injuries in 85.6% (2133/2631) was mine-explosive injury (MIE), in 10.1% (217/2631) - gunshot wounds (GSW), in 4.3% (81/2631) - combined injury (MIE+GSW). Isolated head and neck injuries were diagnosed in only 9.2% of observations.

Most often, a combat-related injury to the head and neck was combined with injuries to the limbs (47.3%) and chest (54.8%). In the case of mine-explosive injury blind penetrating wounds of the head and neck (83.2%) significantly prevailed through (16.8%). In the case of gunshot bullet wounds in head and neck injuries, the specific gravity of through wounds (48.2%) was significantly higher than that of shrapnel wounds (18.3%). Facial fractures of the damaged organs of the maxillofacial area and oral (88.6%) significantly prevailed through (11.4%).

In the structure of the facial fractures, the fractures of the mandible were damaged in 48.5%, the mandible body - in 46.0%, the mandible symphysis - in 31.4%, the mandible ramus - in 26.3% of the wounded, the fractures of the midface - in 23, 5% of wounded, Le For I – in 17.1%, Le For II -in 18.3%, Le For III – in 19.6%, zygoma – in 18.8%, naso-orbito-ethmoid complex – in 16.5%, orbit – in 5.9%, nose - in 5,2%, and frontal sinus - in 4.9%.

PATIENT DEMOGRAPHICS AND RISK FACTORS FOR HAIS

Characteristics in patients with combat-related head and neck injuries and risk factors for HAI in patients are shown in Table 2.

The prevalence of HAIs was highest among patients admitted to ICUs with length of stay in ICU ≥5 days. The most common HAI types in the ICU were PNEU, UTIs and BSIs. Unsurprisingly, Surgical site infection, bone and joint infection (osteomyelitis), and Eye, ear, nose, throat, or mouth infection were the predominant HAI

Table 1. Distribution of 1,075 healthcare-associated infections (HAIs) after maxillofacial and oral surgery procedures among 2,631 patients with combat-related head and neck injuries in Ukraine, 2022-2025

Type of HAI	Total	
	n (%)	95% CI
Surgical site infection	581 (54.0)	53.0 - 55.0
Bone and joint infection	153 (14.2)	13.5 - 14.9
Pneumonia	131 (12.2)	11.7 - 12.8
Urinary tract infection	92 (8.6)	8.1 – 9.2
Bloodstream infection	71 (6.6)	6.1 – 7.1
Eye, ear, nose, throat, or mouth (EENT) infection*	47 (1.9)	4.0 – 4.8
Total	1,075 (100.0)	39.9 – 41.9

CI, confidence interval.
* EENT infection including: conjunctivitis (14 cases), mastoid infection (14 cases), eye infection, other than conjunctivitis (3 cases), sinusitis (5 cases), oral cavity infection (3 cases), upper respiratory tract infection (3 cases), pharyngitis (4 cases), laryngitis (2 cases), and epiglottitis (1 cases).
Source: compiled by the authors of this study

Table 2. Characteristics and risk factors for healthcare-associated infections (HAIs) (n=1.075) in patients (2,631) with combat-related head and neck injuries in Ukraine, 2022-2025

Variable	All patients n	HAI Yes n	HAI Yes %	HAI No n	HAI No %	P-value
Age (full years at the time of injury)						0.24
20-25	388	268	69.1	120	30.9	
26-30	311	129	41.5	182	58.5	
31-35	619	201	32.5	418	67.5	
36-40	311	136	43.7	193	56.3	
41-45	310	98	31.6	212	68.4	
46-50	386	112	29.0	274	71.0	
51-55	231	118	51.1	113	48.9	
≥56	75	13	17.3	62	82.7	
Social status						0.31
civilian	47	17	36.2	30	63.8	
military	2.584	1.058	40.9	1.526	59.1	
Harmful habits						0.074
smoking	2.417	718	29.7	1.699	70.3	
alcohol	136	43	31.6	93	68.4	
Type of injury						<0.001
Mine-Explosive Injury (MIE)	2.133	673	31.6	1.460	68.4	
Gunshot wound (GSW)	217	25	11.5	192	88.5	
Combined injury (MIE+GSW)	81	14	17.3	67	82.7	
Location of soft tissue wounds of the head						0.04
oral/perioral auricular	1.873	621	33.2	1.252	66.8	
scalp	437	47	10.8	390	89.2	
periorbital	95	8	8.4	87	91.6	
perinasal	112	9	8.0	103	92.0	
other	47	3	6.4	44	93.6	
Time from the moment of injury to the first specialized medical help (hours)						<0.001
less then 24 h.	1.109	176	15.9	933	84.1	
24-48 h.	798	341	42.7	457	57.3	
>48 h.	724	558	77.1	166	22.9	
Length of stay in ICU >5 (days)	574	447	77.9	127	22.1	<0.001
Intubation within 48 h before onset	242	131	71.2	111	28.8	0.002
Central venous catheter within 48 h before onset	102	66	64.7	36	35.3	0.05
Peripheral vascular catheter within 48 h before onset	9	3	33.3	6	66.7	0.19
Urinary catheter within 7 days before onset	93	86	92.5	7	7.5	0.001

Source: compiled by the authors of this study

type in surgery departments.

In this study patient risk factors for HAIs included 2,631 patients with combat-related head and neck injuries after maxillofacial and oral surgery procedures. All risk factors were significantly associated with the prevalence of HAIs (P<0.001 after adjustment for all factors in the model) in patients with combat-related head and neck injuries after maxillofacial and oral surgery procedures. Also, 76.5% risk factor sub-levels included in the model were significantly associated at the P<0.001 level, while five risk factor levels were included for consistency although they were signifi-

Table 3. Distribution of micro-organisms (n=2,794) causing HAIs isolated from patients with combat-related head and neck injuries after maxillofacial and oral surgery procedures in Ukraine, 2022-2025

Microorganism	n	%
Gram-positive cocci	**648**	**23.2**
Staphylococcus aureus	154	5.5
Coagulase-negative staphylococci (CoNS)	128	4.6
Enterococcus faecalis	192	6.9
Enterococcus faecium	93	3.3
Streptococcus pneumoniae	69	2.5
Other Gram-positive cocci	12	0.4
Gram-negative bacilli	**1.990**	**71.2**
Escherichia coli	536	19.2
Enterobacter cloacae	127	4.5
Enterobacter aerogenes	88	3.1
Citrobacter spp.	28	1.1
Klebsiella pneumonia	203	7.3
Klebsiella oxytoca	81	2.9
Proteus vulgaris	37	1.3
Proteus mirabilis	72	2.6
Proteus morganii	23	0.8
Providencia rettgeri (Proteus rettgeri)	42	1.5
Serratia marcescens	153	5.5
Acinetobacter lwoffii	93	3.3
Acinetobacter baumannii	184	6.6
Pseudomonas aeruginosa	211	7.6
Stenotrophomonas maltophilia	112	4.1
Fungi	**156**	**5.6**
Candida spp.	125	4.5
Aspergillus spp.	24	0.9
Other fungi	7	0.3
Total	**2.794**	**100.0**

Source: compiled by the authors of this study

cantly associated at the P<0.05 level (type of fractures, location of soft tissue wounds of the head, and central venous catheter within 48 h before onset). The strongest independent associations for HAIs in patients with combat-related head and neck injuries after maxillofacial and oral surgery procedures were observed for length of stay in ICU ≥5 days before HAI onset, mine-explosive injury (MIE), time from the moment of injury to the first specialized medical help and the presence of intubation within >48 h before onset and urinary catheters within 7 days before onset (before the onset of pneumonia and UTIs, respectively).

RESPONSIBLE PATHOGENS OF HAIS AND ANTIMICROBIAL RESISTANCE

In this study 2,794 specimens were isolated from 1,075 patients with HAIs. In the structure of the responsible pathogens of HAIs the Gram-positive cocci were damaged in 24.9%, Gram-negative bacilli - in 78.3%, and fungi - in 5.8%/ Overall, predominated *E. coli* (19.2%), *Pseudomonas aeruginosa* (7.6%), *Klebsiella pneumonia* (7.3%), *Enterococcus faecalis* (6.9%), *Acinetobacter baumannii* (6.6%), *Staphylococcus aureus* (5.5%), *Serratia marcescens* (5.5%), followed by Coagulase-negative staphylococci (CoNS) (4.6%), *Enterobacter cloacae* (4.5%), *Candida* spp. (4,5%), *Stenotrophomonas maltophilia* (4.1%), *Enterococcus faecium* (3.3%), *Acinetobacter lwoffii* (3.3%), *Enterobacter aerogenes* (3.1%), and other pathogens (Table 3).

Gram-positive bacteria were the most common causes of SSIs, bone and joint infection (osteomyelitis), eye, ear, nose, throat, or mouth infection (EENT) and BSIs, and Gram-negative bacteria were the most common causes of respiratory tract infections (pneumonia),

Table 4. Distribution of micro-organisms causing HAIs isolated from patients with combat-related head and neck injuries after maxillofacial and oral surgery procedures, and AMR phenotype, by bacterial species and antimicrobial group/agent, Ukraine, 2022-2025

Bacterial species	Antimicrobial group/agent	AMR, %
Escherichia coli	Aminopenicillin (amoxicillin/ampicillin) resistance	64.7
	Third-generation cephalosporin (cefotaxime/ceftriaxone/ceftazidime) resistance	43.6
	Carbapenem (imipenem/meropenem) resistance	14.7
	Fluoroquinolone (ciprofloxacin/levofloxacin/ofloxacin) resistance	40.1
	Aminoglycoside (gentamicin/netilmicin/tobramycin) resistance	24.1
	Combined resistance to third-generation cephalosporins, fluoroquinolones, and aminoglycosides	11.2
Klebsiella pneumoniae	Third-generation cephalosporin (cefotaxime/ceftriaxone/ceftazidime) resistance	64.8
	Carbapenem (imipenem/meropenem) resistance	49.8
	Fluoroquinolone (ciprofloxacin/levofloxacin/ofloxacin) resistance	66.5
	Aminoglycoside (gentamicin/netilmicin/tobramycin) resistance	61.7
	Combined resistance to fluoroquinolones, third-generation cephalosporins, and aminoglycosides	55.2
Pseudomonas aeruginosa	Piperacillin-tazobactam resistance	47.3
	Ceftazidime resistance	45.6
	Carbapenem (imipenem/meropenem) resistance	59.8
	Fluoroquinolone (ciprofloxacin/levofloxacin) resistance	53,3
	Aminoglycoside (gentamicin/netilmicin/tobramycin) resistance	51.1
	Combined resistance to ≥3 antimicrobial groups (among piperacillin-tazobactam, ceftazidime, carbapenems, fluoroquinolones, and aminoglycosides)	48.4
Acinetobacter baumannii	Carbapenem (imipenem/meropenem) resistance	65.8
	Fluoroquinolone (ciprofloxacin/levofloxacin) resistance	71.1
	Aminoglycoside (gentamicin/netilmicin/tobramycin) resistance	69.8
	Combined resistance to carbapenems, fluoroquinolones, and aminoglycosidesc	65.3
Staphylococcus aureus	Meticillin-resistant S. aureus (MRSA)	35.1
Streptococcus pneumoniae	Penicillin non-wild-type	6.7
	Macrolide (azithromycin/clarithromycin/erythromycin) resistance	5.9
	Combined penicillin non-wild-type and resistance to macrolidesc	3.7
Enterococcus faecalis	High-level gentamicin resistance	49.1
Enterococcus faecium	Vancomycin resistance	15.9

Source: compiled by the authors of this study

UTIs and SSIs.

Antimicrobial susceptibility testing data were available on the day of the survey for 97.1% of Gram-positive and Gram-negative bacteria as causing HAIs. Distribution of micro-organisms causing HAIs isolated from patients with combat-related head and neck injuries after maxillofacial and oral surgery procedures, and AMR phenotype, by bacterial species and antimicrobial group/agent, Ukraine, 2022-2025 are shown in Table 4.

DISCUSSION

The results presented in this study are based on multicentre prospective surveillance data for HAI in patients with combat-related head and neck injuries in Ukraine and antimicrobial resistance of responsible pathogens these infections. This study expands upon the previous reports [6, 8, 9, 17] and is the first study to publish frequent pathogens and characterization of the phenotypic mechanisms of responsible pathogens of HAIs isolated from patients with combat-related head and neck injuries after maxillofacial and oral surgery procedures in Ukraine.

This survey identified a high prevalence of HAI (40.9%) among patients with combat related head and neck injuries, who has undergone maxillofacial or/and oral surgery procedures. A previous study in Ukraine found that prevalence of HAI rate among patients with combat-related injuries and wounds were from 30.2% [6] to 68.6% [17]. No data in the literature on the prevalence of HAIs among patients with combat injuries and wounds in other countries.

In this study the most frequent types of HAI in patients with combat-related head and neck injuries after maxillofacial and oral surgery procedures were SSIs (54%), bone and joint infection (osteomyelitis) (14.2%), PNEU (12.2%), UTIs (8.6%), BSIs (6.6%), and EENT infection (4,4%). The prevalence of HAI among patients with combat-related head and neck injuries varied widely in regions of Ukraine. A previous study in Ukraine found that of the total cases of HAIs in patients with combat-related injuries and wounds, 27.3% were SSI, 25.6% bone and joint (BJ) infections, 15.7% skin and soft tissue infections (SST), 9.7% BSI, 7.9% central nervous system infections (CNS), 5.3% PNEU, 4.1% UTI, 1.7% EENT infections [17]. Our results are consistent with those of previous studies [6, 17].

In this study among patients with HAIs a mild combat-related head and neck injuries was diagnosed in 4.7% of the wounded, severe – in 71.8%, extremely severe – in 23.5%. The cause of combat-related head and neck injuries in 85.6% was mine-explosive injury (MIE), in 10.1% - gunshot wounds (GSW), in 4.3% - combined injury (MIE+GSW). Isolated head and neck injuries among patients with HAIs were diagnosed in only 9.2% of observations. A previous study in Ukraine found that among patients with HAIs a mild combat injury was diagnosed in 15.5% of the wounded, severe – in 72.4%, extremely severe – in 12.1% [17]. Most often, a combat-related injury to the head and neck was combined with injuries to the limbs (47.3%) and chest (54.8%). In the case of mine-explosive injury blind penetrating wounds of the head and neck (83.2%) significantly prevailed through (16.8%). In the case of gunshot bullet wounds in head and neck injuries, the specific gravity of through wounds (48.2%) was significantly higher than that of shrapnel wounds (18.3%). Facial fractures of the damaged organs of the maxillofacial area and oral (88.6%) significantly prevailed through (11.4%).

In this study all risk factors were significantly associated with the prevalence of HAIs in patients with combat-related head and neck injuries after maxillofacial and oral surgery procedures. The strongest independent associations for HAIs in patients with combat-related head and neck injuries after maxillofacial and oral surgery procedures were observed for length of stay in ICU ≥5 days before HAI onset, mine-explosive injury (MIE), time from the moment of injury to the first specialized medical help and the presence of intubation within >48 h before onset and urinary catheters within 7 days before onset (before the onset of pneumonia and UTIs, respectively). Also, while five risk factor levels were significantly associated at the P<0.03 - 0.05 level (type of fractures, location of soft tissue wounds of the head, and central venous catheter within 48 h before onset).

In the structure of the responsible pathogens of HAIs the Gram-positive cocci were damaged in 24.9%, Gram-negative bacilli - in 78.3%, and fungi - in 5.8%/ Overall, predominated *E. coli*, *P. aeruginosa*, *K. pneumonia*, *E. faecalis*, *A. baumannii*, *S. aureus*, and *S. marcescens*. In this study, Gram-negative bacteria (GNB) were the most common pathogens of HAIs, in agreement with several studies in the USA [18], Europe [19], Mexico [20], Brazil [21], China [22], Singapore [23], and Turkey [24].

Antimicrobial susceptibility testing data were available on the day of the survey for all of micro-organisms reported as causing HAIs in patients with combat-related head and neck injuries after maxillofacial and oral surgery procedures. Of the all isolates antibiotic susceptibility tested, 31.7% were found to be multidrug-resistant organisms (MDROs). In this study meticillin resistance was found in 35.1% of *S. aureus* (MRSA) isolates, and vancomycin resistance was found in 15.9% of enterococci. Non-susceptibility to third-generation cephalosporins was detected in 64.8% of *K. pneumoniae* and in 43.6% *E. coli*. Carbapenem resistance was found in 59.8%, 65.8%, 14.7% and 49.8% of *P. aeruginosa* and *A. baumannii* isolates, *E. coli*, and *K. pneumoniae,* respectively. The high rates of resistance to multiple antibiotics found in this study are of concern. According to the literature, there has been an increase in antibiotic-resistant pathogens of HAIs since the start of the Eastern Ukraine military conflict [17]. This was also observed in conflicts in Afghanistan and Iraq [25, 26], Syria [27], Congo [28], and Gaza [29].

STRENGTHS AND LIMITATION

One strength of the present study was that it was a prospective multicentre observational cohort study, based on surveillance data of HAIs in patients with combat-related injuries. Also, this was the first study to publish frequent pathogens and characterization of the phenotypic mechanisms of responsible pathogens of HAIs isolated from patients with combat-related head and neck injuries after maxillofacial and oral surgery procedures in Ukraine. The limitations of this study include in conduct only a civilian hospital of Ukraine. Therefore, the results may not be representative of military hospitals with different distributions of HAI cases in patients with combat-related head and neck injuries and antimicrobial resistance of responsible pathogens of HAIs after maxillofacial and oral surgery procedures.

CONCLUSIONS

This study found a high prevalence of HAIs in patients with combat-related head and neck injuries who has undergone maxillofacial or/and oral surgery procedures caused by MDROs, varying depending on the bacterial species, and antimicrobial group. The incidence of HAIs after maxillofacial and oral surgery in these patients varying widely depending on risk factors such as length of stay in ICU ≥5 days before HAI onset, mine-explosive injury, time from the moment of injury to the first specialized medical help and the presence of intubation within >48 h before onset, urinary catheters within 7 days before onset, AMR of the responsible pathogens, location of soft tissue wounds of the head, and central venous catheter within 48 h before onset, and surgical approach. These findings highlight the need for targeted prevention strategies to mitigate these risks and implement advanced infection control measures based on HAI and AMR surveillance data. Additionally, perioperative management strategies, particularly the use of prophylactic antibiotics, play a crucial role in HAIs prevention in patients with combat-related head and neck injuries who has undergone maxillofacial or/and oral surgery procedures.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

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