Original Article

Prevalence of Traumatic Brain Injury and Associated Infections in a Trauma Center in Northern India

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Abstract

Introduction: One of the rapidly escalating public health problems worldwide is traumatic brain injury (TBI) due to road traffic accidents. In comparison to postneurosurgery patients and other patients inhabiting the intensive care units (ICUs), patients with TBI are more susceptible to nosocomially acquired infections from the hospital milieu. **Methods:** This retrospective study was conducted at a university hospital in Northern India from December 2018 to September 2022. All patients presenting with TBI formed the cohort of our study population. **Results:** A total of 72 patients with TBI were enrolled. The mean age of patients was 40.07 ± 18.31 years. The most common infections were ventilator-associated pneumonia (VAP) (44/72, 61.11%) and bloodstream infection (BSI) in 21 (21/72, 29.17%) patients. Concomitant infections were observed in 21 (21/72, 29.17%) patients. The common organism causing VAP was *Acinetobacter* spp. (29/58, 50.0%), BSI was *Klebsiella pneumoniae* (10/23, 43.48%), urinary tract infection was *K. pneumoniae* (5/16, 31.25%), and surgical site infection was *Acinetobacter* spp. (3/8, 37.5%) in TBI patients. An increased incidence of multidrug resistance was demonstrated in our patients. The increased length of hospital and ICU stay, ICU admission, intubation, diabetes mellitus, chronic kidney disease, and hypertension were statistically significant parameters that made TBI patients prone to develop an infection. **Conclusion:** TBI patients suffering from underlying comorbidities are prone to develop infections with multidrug-resistant bacteria was observed among our study cohort which also mirrors the lack of adherence to infection control measures.

Keywords: Bloodstream infection, drug resistance, infection control, intensive care units, traffic accidents, traumatic brain injury, ventilator-associated pneumonia

Introduction

One of the rapidly escalating public health problems worldwide is attributed to traumatic brain injury (TBI) due to road traffic accidents.[1,2] In comparison to postneurosurgery patients and other patients inhabiting the intensive care units (ICUs), patients with TBI are more susceptible to nosocomially acquired infections from the hospital milieu.[3,4] TBI is defined as "traumatically induced structural injury or physiological disruption of brain function as a result of an external force" by the United States Department of Defense[5] and widespread recognition of this definition is guaranteed by interagency initiatives.[6]

TBI is identified as a form of acquired brain injury which is diagnosed either at the time of injury or within the first 24 h of injury. It may be open (penetrating) or closed (nonpenetrating). The clinical hallmark of acute brain injury is the Glasgow Coma Scale (GCS). It is used as a diagnostic measure to assess the cognitive functions of TBI patients on arrival in the emergency department.[7] The Centers for Disease Control and Prevention (CDC) has estimated that each year, approximately 1.5 million people survive a TBI in the United States of America,[8] among whom approximately 230,000 are hospitalized[9] and death is reported in 50,000 Americans following TBI[10] with the most common causes attributed to motor vehicle accidents, violence, and falls.[11] In India, the total burden of TBI is unknown due to the low quality of quantitative studies, a few of them suggest more than a million

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trauma related deaths occurring in India per year, of which 50% are TBI related.[12] Severe cases of TBI account for <10% of cases, but they account for an estimated cost of 400 billion dollars every year in global cost.[13,14]

Rationale for investigation

We came across limited studies mentioning the incidence of nosocomial infections, risk factors, and the incidence of drug resistance in TBI patients. We conducted this retrospective study in the trauma center of a university hospital in Northern India to assess the risk factors, the incidence of nosocomial infections, and their drug susceptibility pattern and microbiology of the infections in this population.

Objectives

The main aim of the study was to observe the prevalence of TBI and associated infections in patients at a specialized trauma center of a tertiary care center.

The objectives of this study include:

- Identification of the risk factors and underlying comorbidities that render susceptibility to infections in TBI patients
- Analysis of the spectrum of pathogenic bacteria and drug resistance among the pathogens isolated from infections in TBI patients.

Methods

Study design

We performed a retrospective study where respiratory, blood, urine, and pus samples from patients with TBI following road traffic accidents were investigated for infections and associated risk factors.

Setting

This study was conducted in the bacteriology section of the microbiology department in the trauma center of a university hospital in Northern India from December 2018 to September 2022. All patients who presented with TBI formed the cohort of our study population. Records of baseline GCS score values and all other clinical data were extracted from patient files and the hospital information system. The study was approved by the institute ethics committee (2021-48-EMP-EXP dated November 29, 2021). All procedures were followed in accordance with the ethical standards of the responsible committee on human experimentation (institutional or regional) and with the Helsinki Declaration of 1975. Informed consent was waived off as there was no intervention and no privacy data were obtained.

Participants

The participants of the study include all patients with TBI and the subset of patients who suffered from post-TBI infections.

Inclusion criteria

All respiratory, blood, urine, and pus samples from patients with TBI admitted to the trauma center of the university hospital were included.

Exclusion criteria

Any sample that was reported to be contaminated on culture and all skin contaminants and commensals were excluded from the study while analyzing the infective microorganisms.

Variables

All clinical data extracted from case files of TBI patients and the hospital information system were reviewed for underlying comorbidities, associated infections and co-infections, length of hospital stay, ICU admission, and length of ICU stay. The samples were aseptically inoculated on blood agar and MacConkey agar plates incubated aerobically at 35°C–37°C for 24–48 h.

Bacterial isolates were identified by routine biochemical testing and matrix-assisted laser desorption/ionization-time of flight mass spectrometry (MALDI-TOF-MS). Kirby–Bauer disc diffusion method was used to perform antibiotic sensitivity testing according to the Clinical and Laboratory Standards Institute guidelines 2019.[15] Multidrug resistance (MDR) was identified as resistance to three or more classes of antibiotics and extensive drug resistance (XDR) was identified as resistance to drugs of last resort.

Bias

As this is a retrospective cohort study where most of the data were obtained from the hospital information system and laboratory register, there is a possibility of information bias attributable to lack of any information maintained in records.

Study size

The sample size was arrived at by retrospectively analyzing culture results of respiratory, blood, urine, and pus samples from TBI patients for the past 4 years from the hospital information system.

Quantitative variables

Most of the quantitative data like age of the patients were obtained from the hospital information system. The GCS score of the patients was obtained at admission, mentioned in the electronic data system. The length of ICU stay and ICU admission was mentioned in the electronic records. The duration of hospital stay among our patients was calculated from the day of patient admission to the day of the next outpatient department visit which was obtained from the electronic records.

Statistical methods

The statistical analysis for our study was performed by observing frequencies. Quantitative variables were expressed as mean and standard deviation. In the analysis of risk factors for MDR, the comparison between groups for categorical variables was estimated using Chi-square tests. The results were presented as 95% confidence intervals. Statistical analysis was performed using the software program IBM SPSS Statistics version 20.0 (SPSS Inc., Armonk, NY, USA), with $P < 0.05$ considered statistically significant.

Results

Participants

Seventy-two patients with TBI were enrolled in the study duration of 4 years. The cause of TBI was attributed to a fall from a vehicle or road traffic accident in 83.33% (60/72) of patients, followed by a fall from height in 11.11% (8/72) of patients and assault in 5.56% (4/72) of patients. Forty (40/72, 55.56%) patients were subjected to intracranial surgeries as a consequence of TBI, and all of them were subjected to a minimum of one procedure.

Descriptive data

The mean age of the patients was 40.07 ± 18.31 years in our study cohort. Forty (40/72, 55.56%) patients underwent intracranial surgeries as a consequence of TBI; the most common surgery performed among these patients was craniotomy (30/72, 41.7%) followed by burr hole (8/72, 11.11%). The median length of hospital stay among these patients was 14 days (range, 1–57). The length of hospital stay was higher in those admitted to the ICUs.

We compared the baseline demographics, the perioperative characteristics, and the outcome between patients who underwent neurosurgery and those who did not. The value of GCS was observed to be lower in patients who underwent neurosurgery and was statistically significant in comparison to those patients who did not undergo neurosurgery [Table 1]. Over 4 years, 93.06% (67/72) of patients with TBI were subjected to ICU stay. Of the 77 patients admitted to the ICU, 58.21% (39/67) were intubated and 38.80% (26/67) underwent tracheostomy. Significantly higher cases of ICU admission, intubation, and tracheostomy were observed among patients who underwent neurosurgery [Table 1].

Main Results

The infections predominantly encountered in our study cohort were ventilator-associated pneumonia (VAP), bloodstream infection (BSI), urinary tract infection (UTI), and surgical site infection (SSI). The most common infection encountered was VAP (44/72, 61.11%) followed by BSI in 21 (21/72, 29.17%) patients. Concomitant infections were observed in 21 (21/72, 29.17%) patients. VAP, BSI, UTI, and SSI were statistically significant in patients undergoing neurosurgery in comparison to those who did not undergo neurosurgery [Table 1]. Higher incidences of adverse outcomes were observed in TBI patients who underwent surgery.

Among the underlying comorbidities observed in TBI patients, Type 2 diabetes mellitus, hypertension, and chronic renal failure were significantly prone to develop infections. Patients who underwent ICU admission, intubation, and tracheostomy were statistically significant to develop nosocomial infections along the course of the hospital stay [Table 2]. An increase in the length of ICU stay and death was reported in patients who developed infections.

Table 1: Comparison of the baseline characteristics, the infectious complications, the perioperative characteristics, and the outcome between patients who did and did not undergo neurosurgery (*n*=72)

Features	Patients who underwent neurosurgery (*n*=39; 54.17%)	Patients who did not undergo neurosurgery (*n*=33; 45.83%)	95% CI	*P*
Gender (male: female)	30:9	29:4	1.65–1.93	0.229
Age (years), mean±SD	44.97±18.28	35.57±17.67	-	0.030*
Comorbidities, *n* (%)				
Diabetes mellitus	15 (38.46)	11 (33.33)	1.44–1.77	0.652
Coronary atherosclerotic disease	2 (5.13)	1 (3.03)	1.87–2.02	0.657
Hypertension	14 (35.89)	10 (30.30)	1.50–1.82	0.616
Hypothyroidism	2 (5.13)	3 (9.09)	1.83–2.02	0.510
Cerebrovascular accident	2 (5.13)	0	1.87–2.02	0.181
Chronic renal failure	6 (15.38)	5 (15.15)	1.72–1.96	0.978
Acute renal failure	5 (12.82)	2 (6.06)	1.72–1.96	0.690
Concomitant infections	21 (53.85)	0	1.30–1.63	<0.001*
VAP	30 (76.92)	14 (42.42)	1.09–1.37	0.003*
Bloodstream infections	17 (43.59)	4 (12.12)	1.40–1.73	0.009*
Urinary tract infection	12 (30.77)	2 (6.06)	1.54–1.84	0.008*
Surgical site infection	7 (17.95)	0	1.69–1.95	0.010*
Admission GCS, mean±SD	6.97±3.53	8.93±3.64	-	0.023*
Intubation	39 (100)	27 (81.82)	0.99–1.21	0.012*
Tracheostomy	26 (66.67)	1 (3.03)	1.18–1.49	<0.001*
ICU admission	39 (100)	28 (84.85)	0.99–1.19	0.05*
ICU length of stay, mean±SD	14.28±6.29	10.70±8.33	-	0.042*
Length of hospitalization, mean±SD	24.33±13.56	17.30±14.04	-	0.033*
Death	21 (53.85)	10 (30.30)	1.27–1.60	0.044*

*P<0.05 is statistically significant. SD: Standard deviation, CI: Confidence interval, GCS: Glasgow Coma Scale, ICU: Intensive care unit, VAP: Ventilator-associated pneumonia

Eighty-six episodes of infections were observed among 72 TBI patients. Both monomicrobial and polymicrobial infections were observed in the bacterial culture results of these episodes [Figure 1]. While monomicrobial infections were predominantly observed in the 86 episodes, the incidence of polymicrobial infections among VAP, BSI, UTI, and SSI was 31.82% (14/44), 9.52% (2/21), 14.28% (2/14), and 14.28% (1/7), respectively.

Forty-four episodes of VAP were caused by 58 microorganisms; the most common organism causing VAP was *Acinetobacter* spp. (29/58, 50.0%), followed by *Klebsiella pneumoniae* (15/58, 25.86%) and *Pseudomonas aeruginosa* (6/58, 10.34%). Twenty-one episodes of BSI were recorded and their causative microorganisms were 23 in number. The most common BSI was caused by *K. pneumoniae* (10/23, 43.48%) followed by *Acinetobacter* spp. (5/23, 21.74%) and methicillin-resistant *Staphylococcus aureus* (3/23, 13.04%). Fourteen episodes of UTI were recorded and their causative microorganisms were 16 in number. The most common uropathogen was *K. pneumoniae* (5/16, 31.25%) followed by *Enterococcus* spp. (5/16, 31.25%) and *Escherichia coli* (4/16, 25.0%). Seven episodes of SSI were recorded and their causative microorganisms were 8 in number. SSI was most commonly caused by *Acinetobacter* spp. (3/8, 37.5%), followed by *K. pneumoniae* (2/8, 25.0%) and *E. coli* (1/8, 12.5%) [Table 3].

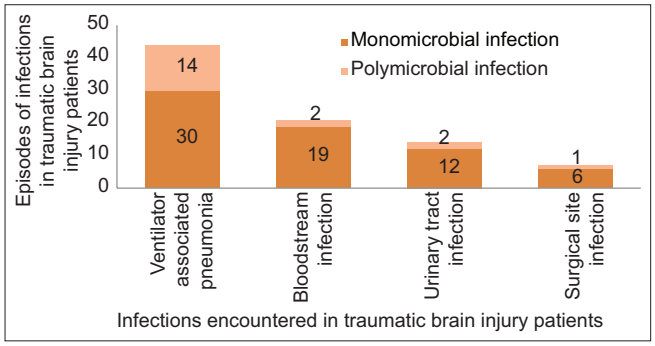

Figure 1: The distribution of polymicrobial or monomicrobial isolated episodes of infections in traumatic brain injury patients included in the study (n = 86)

An increased incidence of MDR was demonstrated by the antimicrobial susceptibility pattern of the microorganisms causing infections in TBI patients. Among the 105 microorganisms isolated from the 86 episodes of infections, 99 (99/105, 94.28%) Gram-negative bacilli (GNB) were isolated from infections in TBI patients. Most MDR isolates among the GNB were *Acinetobacter* spp. (38), followed by *K. pneumoniae* (32), *Pseudomonas* spp. (10), *E. coli* (9), and *Enterobacter* spp. (1) [Table 4]. A total of 11 (11/105, 10.48%) Gram-positive cocci (GPC) isolates were identified among the bacteria causing infection in TBI patients. Among the GPC, antibiotic resistance was demonstrated in methicillin-sensitive/resistant *S. aureus* (MRSA/MSSA) (6) and *Enterococcus* spp. (5).

Resistance to the five major classes of antibiotics was noted in 90 (90/105, 85.71%) GNB. Aminoglycoside resistance among GNB was demonstrated in 88 (88/90, 97.78%) Gram-negative isolates. Maximum resistance to aminoglycosides was observed among *Acinetobacter* spp. (38/38, 100%) and *Pseudomonas* spp. (10/10, 100%) followed by 93.75% (30/32) of *K. pneumoniae* and 77.78% (7/9) of *E. coli* isolates. Among GPC isolates, 33.33% (2/6) of isolates of MRSA and all isolates of *Enterococcus* spp. (5/5, 100%) were found resistant to aminoglycosides. A high resistance of >90% to the group was observed among *Acinetobacter* spp. (37/38, 97.37%), *K. pneumoniae* (29/32, 90.625%), and *Pseudomonas* spp. (9/10, 90.0%).

E. coli (9/9, 100%) and *Enterobacter* spp. (1/1, 100%) were found to be completely resistant to beta-lactam (BL) antibiotics and BL and beta-lactamase inhibitor (BL-BLI) antibiotics.

Table 2: Characteristics of traumatic brain injury patients who did or did not develop an infectious complication (n=72)

Features	No infection (n=17), n (%)	Infection (n=55), n (%)	95% CI	P
Gender (male: female)	12:5	47:8	1.78–1.96	0.164
Age (years), mean±SD	28.20±13.91	42.24±18.13	-	0.0045*
Comorbidities, n (%)				
Diabetes mellitus	2 (11.76)	24 (43.64)	1.42–1.69	0.017*
Coronary atherosclerotic disease	1 (5.88)	2 (3.64)	1.91–2.01	0.685
Hypertension	2 (11.76)	22 (40.0)	1.48–1.75	0.031*
Hypothyroidism	2 (11.76)	3 (5.45)	1.88–2.01	0.371
Cerebrovascular accident	0	2 (3.64)	1.91–2.01	0.421
Chronic renal	0	11 (20.0)	1.69–1.91	0.045*
Acute renal failure	2 (11.76)	5 (9.09)	1.78–1.96	0.745
Intubation	13 (76.47)	53 (96.36)	0.99–1.09	0.009*
Tracheostomy	2 (11.76)	25 (45.45)	1.42–1.69	0.012*
ICU admission	13 (76.47)	54 (98.18)	0.98–1.06	0.002*
ICU length of stay, mean±SD	7.87±5.50	12.63±7.53	-	0.0186*
Length of hospitalization, mean±SD	13.07±8.56	20.94±14.53	-	0.0379*
Death	3 (17.65)	28 (50.90)	1.37–1.65	0.015*

*P<0.05 is statistically significant. SD: Standard deviation, CI: Confidence interval, ICU: Intensive care unit

Table 3: Sites of infection and pathogenic bacteria most commonly isolated in traumatic brain injury patients included in the study

Infection site	Number of infections (%) (*n*=86)	Number of organisms isolated (%) (*n*=105)	Organisms isolated (*n*=105)
VAP	44 (51.16)	58 (55.24)	*Acinetobacter spp*. (*n*=29; 50.0%)
			K. pneumoniae (*n*=15; 25.86%)
			P. aeruginosa (*n*=6; 10.34%)
			E. coli (*n*=3; 5.17%)
			P. stuartii (*n*=2; 3.45%)
			MRSA (*n*=2; 3.45%)
			S. marcescens (*n*=1; 1.74%)
BSI	21 (24.42)	23 (21.90)	*K. pneumoniae* (*n*=10; 43.48%)
			Acinetobacter spp. (*n*=5; 21.74%)
			MRSA (*n*=3; 13.04%)
			E. coli (*n*=1; 4.35%)
			E. cloacae (*n*=1; 4.35%)
			MSSA (*n*=1; 4.35%)
			P. aeruginosa (*n*=1; 4.35%)
			P. putida (*n*=1; 4.35%)
UTI	14 (16.28)	16 (15.24)	*K. pneumoniae* (*n*=5; 31.25%)
			Enterococcus spp. (*n*=5; 31.25%)
			E. coli (*n*=4; 25.0%)
			Acinetobacter spp. (*n*=1; 6.25%)
			P. mirabilis (*n*=1; 6.25%)
SSI	7 (8.14)	8 (7.62)	*Acinetobacter* spp. (*n*=3; 37.5%)
			K. pneumoniae (*n*=2; 25.0%)
			E. coli (*n*=1; 12.5%)
			P. aeruginosa (*n*=1; 12.5%)
			P. putida (*n*=1; 12.5%)

VAP: Ventilator-associated pneumonia, SSI: Surgical site infection, UTI: Urinary tract infection, BSI: Bloodstream infections, *K. pneumoniae*: *Klebsiella pneumoniae*, *P. aeruginosa*: *Pseudomonas aeruginosa*, *E. coli*: *Escherichia coli*, *P. stuartii*: *Providencia stuartii*, *S. aureus*: *Staphylococcus aureus*, *S. marcescens*: *Serratia marcescens*, *E. cloacae*: *Enterobacter cloacae*, *P. putida*: *Pseudomonas putida*, *P. mirabilis*: *Proteus mirabilis*, MRSA: Methicillin-resistant *S. aureus*, MSSA: Methicillin-sensitive *S. aureus*

Table 4: Antibiotic resistance among Gram-negative microorganisms against major classes of antimicrobials (*n*=90/105; 85.71%)

Antimicrobial agents	*Acinetobacter* spp. (*n*=38)	*K. pneumoniae* (*n*=32)	*Pseudomonas* spp. (*n*=10)	*E. coli* (*n*=9)	*Enterobacter* spp. (*n*=1)	Total (*n*=90)
Aminoglycosides, *n* (%)	38 (100.0)	30 (93.75)	10 (100.0)	7 (77.78)	1 (100.0)	88 (97.78)
β-lactam-β lactamase inhibitor combinations, *n* (%)	37 (97.37)	29 (90.625)	9 (90.0)	9 (100.0)	1 (100.0)	85 (94.44)
Third-generation cephalosporins, *n* (%)	38 (100.0)	32 (100.0)	7 (70.0)	9 (100.0)	1 (100.0)	87 (96.67)
Carbapenems, *n* (%)	38 (100.0)	30 (93.75)	10 (100.0)	9 (100.0)	1 (100.0)	88 (97.78)
Fluoroquinolones, *n* (%)	38 (100.0)	31 (96.875)	9 (90.0)	9 (100.0)	1 (100.0)	88 97.78)
Resistance to all above classes of drugs (XDR), *n* (%)	37 (97.37)	27 (84.375)	7 (70.0)	8 (88.89)	1 (100.0)	80 (88.89)

XDR: Extensive drug resistance, *K. pneumoniae: Klebsiella pneumoniae, E. coli: Escherichia coli*

Similarly, a resistance of 100% was observed in *Acinetobacter* spp. (38/38, 100%), *K. pneumoniae* (32/32, 100%), *E. coli* (9/9, 100%), and *Enterobacter* spp. (1/1, 100%) to third-generation cephalosporins and 70% (7/10) resistance was observed in *Pseudomonas* species.

Among the microorganisms isolated from the infections in TBI patients, there was pronounced resistance to the fluoroquinolone and carbapenem group of antibiotics. Resistance of 100% was observed to both fluoroquinolones and carbapenem antibiotics among *Acinetobacter* spp. (38/38, 100%), *E. coli* (9/9, 100%), and *Enterobacter* spp. (1/1, 100%). A resistance of >90% was observed to fluoroquinolones in *K. pneumoniae* (31/32, 96.875%) and *Pseudomonas* spp. (9/10, 90%), whereas a 93.75% (30/32) resistance to carbapenems was observed in *K. pneumoniae* and complete resistance to *Pseudomonas* spp. (10/10, 100%).

XDR was observed in the case of GNB in 80 (80/90, 88.89%) isolates of the 90 most common isolates. *Enterobacter* spp. (1/1, 100%) was identified by MALDI-TOF-MS, and it was also identified as the most XDR microorganism isolated from the bloodstream infection in TBI patients followed by *Acinetobacter* spp. (37/38, 97.37%) commonly isolated from

VAP- and BSI-infected patients and *E. coli* (8/9, 88.89%) isolated from the VAP- and UTI-infected patients.

The increased length of hospital stay, ICU admission, length of ICU admission, tracheostomy, intubation, and comorbidities such as diabetes mellitus, chronic kidney disease, and hypertension were statistically significant parameters that made TBI patients prone to develop an infection.

Discussion

The rationale of this study was to determine the rate and bacteriology of infections, associated risk factors, and rate of MDR in TBI patients. The general sites of infection in our study correspond with previously conducted studies on TBI patients by Boque *et al.*[3] and in other patients suffering from ailments due to trauma.[16]

The mean of age of patients in our study cohort was 40.07 ± 18.31 years (range, 3–79 years) which is similar to the age group of patients in a study by Harna *et al.*[17] with an average age of 33.4 years (range, 2–93 years). We observed a male predominance of 81.9% (59/72, 81.9%) similar to the male predominance observed by Harna *et al.*[17]

The common risk factors rendering TBI patients prone to infections [Table 2] are diabetes mellitus, hypertension, chronic renal failure, intubation, tracheostomy, and ICU admission. The length of ICU stay and length of hospitalization were also significantly associated with a tendency to develop more infections which corroborates with other studies in the literature.[3,18,19]

Patients undergoing prolonged hospital stay with coma, ventilation, and immobilization are at the enormous possibility for posttraumatic complications, like pulmonary infections.[18] The most common microorganism isolated from the VAP or respiratory infections was *Acinetobacter* spp. similar to a study by Kourbeti *et al.*[19] but disagreed with the findings of Boque *et al.*[3] and Papia *et al.*[16] VAP was identified as the most common infection among TBI patients. Forty-four (44/72, 61.11%) cases of VAP were reported from our study, which is high in comparison to 8.4% cases observed in a study by Kourbeti *et al.*[19]

Twenty-one (12/72, 29.17%) BSIs caused by 23 pathogenic microorganisms were identified in our study cohort. BSIs were also higher in comparison to studies previously reported in the literature which was 2.7% and 8% in Kourbeti *et al*.[19] and Boque *et al*.,[3] respectively. A predominance of GNB were responsible for BSI among the TBI patients, which corroborates with studies by Helling *et al*.[20] and Schindler *et al*.[21] and contradicts the evaluation of Kourbeti *et al*.[19] UTI was observed in 19.44% (14/72, 19.44%) of cases encountered in our study cohort and is much higher in comparison to the 3% in Kourbeti *et al*.[19] and 4% in Boque *et al.*[3]

The incidence of VAP was reported as 61.11% (44/72) in our study which is much higher in comparison to a study by Zhang *et al*.[22] reporting pulmonary infections in 26.85% of patients. Our observation of predominant isolation of GNB from respiratory samples of TBI patients with VAP corroborated with a study by Zhang *et al*.[22] *Acinetobacter* spp. is an emerging pathogen in most infections occurring in TBI patients and was reported as the most common microorganism causing VAP in trauma patients in a recent study by Kaur *et al*.[23] Although *K. pneumoniae* was reported to be highly sensitive to levofloxacin, cefoperazone, and meropenem in literature,[24,25] 73.33% (11/15) of isolates identified from our study cohort were extremely drug resistant which included complete resistance to fluoroquinolones (15/15, 100%) and third-generation cephalosporins (15/15, 100%). Therefore, following the antibiotic sensitivity pattern is imperative.

This study also provides insight into the spectrum of antibiotic resistance among the commonly isolated microorganisms causing infections in TBI patients. Out of the 21 cases of BSI, 19 (19/21, 90.47%) were monomicrobial infections, whereas 2 (2/21, 9.52%) were polymicrobial infections. Further, our study explores the predominance of Gram-negative microorganisms like *K. pneumoniae* followed by *Acinetobacter* spp. from BSI which contrasts with the microorganisms isolated from the BSI in the literature that mainly comprises *S. aureus* and coagulase-negative *Staphylococcus*.[26] A high level of drug resistance was observed in the microorganisms isolated from BSI in TBI patients included in our study cohort. All *K. pneumoniae* and *Acinetobacter* spp. isolates were identified to be resistant to five major classes of antibiotics which include aminoglycosides, cephalosporins, BL-BLI combinations, carbapenems, and fluoroquinolones.

The majority of the patients suffering from a TBI are prone to be catheterized on admission and the presence of a urinary catheter attributes to increased chances of UTI.[26] Our study recognized UTI as the third most common infection among TBI patients. *E. coli* were identified as the most resistant isolate from urine samples, showing 100% (4/4) XDR character followed by *K. pneumoniae*, showing 80% (4/5) XDR character. SSI was identified as the fourth most common infection in TBI patients. The incidence of UTI among all cases of infections observed in our study was 8.14% (7/86) which was low in comparison to the 15% cases of UTI identified from previous studies in the literature.[27] All isolates of microorganisms isolated from TBI patients suffering from UTI were identified as the XDR.

The limitation of this study includes the retrospective nature of our data which was extracted from the hospital files and the electronic information system employed in the hospital. Second, the data only state the common infections encountered at our center and do not reflect the same incidence in a larger population.

Conclusion

We state that TBI patients are prone to develop several infections with multidrug-resistant bacteria observed in our

study cohort which also mirrors the lack of adherence to infection control measures.

Research quality and ethics statement

The study was approved by the institute ethics committee (2021-48-EMP-EXP). The authors followed applicable EQUATOR Network (http://www.equator-network.org/) guidelines during the conduct of this research project.

Author contribution

Protocol development: Mitra Kar and Sangram Singh Patel. Data collection: Pooja Singh and Mitra Kar. Data analysis: Sangram Singh Patel, Chinmoy Sahu, and Nidhi Tejan. Supervision: Sangram Singh Patel, Chinmoy Sahu, Kamlesh Bhaisora, and Ujjala Ghoshal. Writing – original draft: Mitra Kar. Writing – review and editing: Mitra Kar, Chinmoy Sahu, Pooja Singh, Kamlesh Bhaisora, Nidhi Tejan, Sangram Singh Patel, and Ujjala Ghoshal.

All authors read and approved the final version of the manuscript.

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Conflicts of interest

There are no conflicts of interest.

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