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Microbiological profile of healthcare–associated infections at a tertiary care center, New Delhi, India

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ABSTRACT

Objective: To determine the incidence and microbiological profile of healthcare-associated infections (HAIs) in a Medical Intensive Care Unit (MICU) in New Delhi, India.

Methods: All patients aged 18 years and above who were admitted to the MICU and suspected of having HAIs by the treating physicians were enrolled in this study. Different samples (pus, blood, urine, and sterile fluid/aspirates) were collected from all patients according to standard protocol. Cultures and microscopy were performed on the samples, and identification of growth was done using biochemical tests and the VITEK-2 system. The antimicrobial susceptibility testing was also conducted according to Clinical and Laboratory Standard Institute guidelines.

Results: Among 81 patients with central lines, urinary catheters, and mechanical ventilation, HAIs were observed in 12 (14.8%) patients. Of these 81 patients, ventilator-associated pneumonia (VAP) occurred in 9 patients (11.1%) and central line-associated bloodstream infection was observed in 3 patients (3.7%). The microorganisms isolated from patients with VAP included *Klebsiella pneumoniae* in 6 cases, *Acinetobacter lwoffii* in 1 case, *Escherichia coli* in 1 case and methicillin-resistant *Staphylococcus aureus* in 1 case. Among the Gram-negative isolates from VAP patients, high resistance was observed in *Escherichia coli* (83.33%) and *Klebsiella pneumoniae* (100%) to both imipenem and meropenem. All the isolates were susceptible to colistin.

Conclusions: The study highlights the high incidence of HAIs in critically ill MICU patients and the alarming prevalence of carbapenem resistance in the HAI-causing pathogens. HAIs are largely preventable through effective infection prevention and control measures.

KEYWORDS: Healthcare-associated infections; Ventilator-associated pneumonia; Central line-associated bloodstream infections; Catheter-associated urinary tract infections

1. Introduction

Healthcare-associated infections (HAIs) are a major cause of morbidity and mortality in Medical Intensive Care Units (MICUs)[1]. The term healthcare-associated infections is applied to any infection causing illness that was neither present nor in its incubation period when the subject entered the hospital or received treatment in an outpatient or accident and emergency department. HAIs usually appear 48 hours after admission up to 30 days after discharge (most commonly within the first 7 days) and up to 1 year after prosthesis operations[2]. The World Health Organization (WHO) estimates that HAIs affect approximately 7% to 12% of patients globally. In India, the burden of HAIs is between 10%-20%[3]. The reported fatality rate in the International Nosocomial Infection Control Consortium (INICC) survey for India ranged

Significance

In intensive care units (ICUs), the presence of invasive devices (central venous catheters, endotracheal tubes, and urinary catheters) increases the risk of healthcare-associated infections (HAIs), which can further lead to mortality and morbidity. This study provides insight into pathogens causing HAIs and their antimicrobial susceptibility patterns in our institution. The findings will contribute significantly to understanding the local resistance trends, and guiding infection control practices and antimicrobial stewardship efforts.

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from 35.2% to 44.9%[4]. The prevalence of HAIs differs across nations and is influenced by economic factors. In low- and middle-income countries, the likelihood of contracting an HAIs can be up to 20 times greater[5].

HAIs are associated with prolonged hospital stay, which increases tremendously the cost of medical care[6]. These infections differ from other non-HAIs because less virulent microbes becoming pathogenic and the host usually being immunosuppressed. HAIs are a major public health concern, representing one of the most common adverse events in healthcare settings, and significantly contributing to morbidity, mortality, and reduced quality of life. In the Intensive Care Unit (ICU), patients frequently require medical devices such as central venous catheters, endotracheal tubes, and urinary catheters. In a tertiary care setting, many ICU admissions are preceded by hospitalization in other units, where challenges in patient management can arise. During hospitalization, regardless of the specific ward, a patient's normal bacterial flora is often replaced by hospital-acquired microbiota. Additionally, prolonged antibiotic use contributes to the selection of drug-resistant microorganisms, increasing the likelihood of colonization by pathogenic, multidrug-resistant bacteria[7]. In a study of South Africa in 2024, there was a mortality rate of 22%[8] which was higher (71%) in Lebanon[9]. In developed countries, up to 7% of patients acquire at least one HAI, while in developing countries, the rate can reach 10%. These infections result in considerable economic costs to society[10]. Importantly, most HAIs are preventable through the application of effective infection prevention and control measures[11]. Common types of HAIs include central line-associated bloodstream infections (CLABSI), catheter-associated urinary tract infections (CAUTI), ventilator-associated pneumonia (VAP), and surgical site infections.

There are very few published studies on the epidemiology of HAIs along with carbapenem resistance in patients being managed in MICUs from India. It is very important to determine the incidence, delineate the profile and characterize the HAIs occurring in cases admitted in MICU (including the risk factors). In this study, we aimed to determine the incidence along with microbiological profile of HAIs in MICU.

2. Material and methods

2.1. Study design and patient recruitment

This prospective cohort study was conducted between November 2019 to March 2021 at Lady Hardinge Medical College & Smt. Sucheta Kripalani Hospital, New Delhi. A prospective cohort study design was chosen because it allows for real-time data collection, minimizes recall bias and ensures accuracy in identifying HAIs. By following patients over time, this design helps establish a temporal relationship between hospitalization and the development of HAIs, which is crucial for understanding causality.

A total of 81 patients admitted to the MICU of Smt. Sucheta Kriplani Hospital who were suspected of having HAIs (as diagnosed by the treating physicians) were assessed and investigated in this study. The sample size for this study was determined using a standard formula for sample size calculation:

$$n = Z^2\, p(1\text{-}p)/(e)^2$$

where Z is 1.96 (for a 95% confidence level), P is the estimated prevalence of HAIs in the MICU, assumed to be 0.05, and e is the margin of error, set at 0.05. The minimum required sample size was 73 patients. To enhance the study's robustness and account for potential dropouts or missing data, the final sample size was increased to 81 patients.

This approach is a sample size estimation rather than a formal power analysis. While power analysis typically ensures that a study has sufficient statistical power to detect a meaningful effect, this calculation primarily aimed to estimate an adequate sample size based on prevalence rates and confidence levels. A larger sample size in future studies could provide more statistically significant findings and a stronger basis for generalizability.

The enrolled patients were aged 18 years and above who were initially admitted and had remained for at least 48 hours in MICU, therefore meeting the criteria of HAIs[12]. The study tracked HAIs from the time of patient admission to the MICU until discharge or death. The patients excluded in study were those having infection at admission/ manifestation of any infective illness within 48 hours of admission as suggested by clinical picture and investigations.

2.2. Specimen collection and transport

Different samples (pus, blood, urine and sterile fluid/aspirates) were collected from all patients using a standard protocol[13]. Efforts were made to transport all samples to the laboratory within 2 hours for further processing. In case of a delay, samples such as urine were stored in sterile containers at 2-8 °C in refrigerator. Other samples such as pus (collected using pus swabs), blood (collected in blood culture bottles) were kept at room temperature (22-25 °C). All samples were transported to the laboratory and processed within 24 hours to identify suspected pathogens.

2.3. Sample processing

Microscopy involving direct wet mount and gram stain were performed on the samples and identification of growth was done by biochemical tests and VITEK-2 system[13]. The cultures including blood culture were done in suspected clinical sepsis cases by automated technique like BACTEC. Urine cultures were also performed using the semi-quantitative culture technique[13]. Antimicrobial susceptibility of the incriminated microorganisms was done using the standard disc diffusion method as per Clinical and Laboratory Standard Institute (CLSI) guidelines[14].

2.4. Statistical analysis

Data was entered and analysed using SPSS version 20. Categorical variables were presented as proportions and continuous variables

were presented as mean±standard deviation (SD) or median with interquartile range (IQR). For comparisons between two groups, the *t*-test was used for normally distributed continuous variables, and Wilcoxon rank-sum test was used for non-normally distributed continuous variables[15]. The *Chi*-square test or Fisher's exact test was used for categorical variables. A difference between three or more groups was performed using ANOVA or the Kruskal-Wallis test. A *P*-value of less than 0.05 was considered statistically significant[15].

2.5. Ethical approval

The study was approved by Scientific Review Board & Ethics Committee of LHMC, New Delhi on August 25, 2022 (LHMC/IEC/2022/03/78).

3. Results

3.1. Incidence of HAIs

Among 81 patients enrolled in the study, HAIs were observed in 12 patients, resulting in an incidence rate of 14.8 per 100 patient admissions (95% *CI*: 7.9-24.5). The incidence density of HAIs was 24.4 per 1 000 patient-days (95% *CI*: 13.9-42.7).

3.2. Age and gender distribution of HAIs

The age group of enrolled patients was 18-81 years, among which 44 (54.3%) were males and 37 (45.7%) were females. The mean age was 47.1±16.5 years, and the median age was 50 years (IQR: 32-60 years). The mean age of patients having HAIs is 51.2±13.4 years, with a similar distribution in males and females (50% each), as seen in Table 1. The age and gender distribution of the enrolled patients provides useful demographic insights into the study population. The mean age of patients with HAIs (51.2±13.4 years) was slightly higher than those without HAIs (46.4±17.0 years), though this difference was not statistically significant (P=0.36). Similarly, the gender distribution was nearly equal among patients with HAIs, with males comprising 50% and females 50%, suggesting no significant gender-biased predisposition to infection (P=0.10).

3.3. Incidence and risk factors of related HAIs associated with invasive devices

Among 81 patients, HAIs were seen in 12 patients. Out of 81 patients, the 11.1% (9/81) and 3.7% (3/81) of VAP and CLABSI were observed in the study population respectively. Central line was inserted in all 81 (100%) patients. Mean duration of central line was 5.9±3.3 days. Median duration of central line was 6 (IQR: 4-7) days. 3.7% (3/81) of CLABSI was observed in the study population. No risk factor was associated with CLABSI in our study. Urinary catheter was inserted 72 (88.9%) patients. The duration range of catheterization was 2-20 days. Mean duration of urinary catheterization was 6.4±3.2 days. Median duration of urinary catheterization was 6 (IQR: 5-7) days. No episode of CAUTI was observed in the enrolled population. No risk factor was associated with CAUTI in our study. Nine episodes (11.1%) of VAP were observed in the study population. Total ventilator days during the study period was 369. Using the CDC/NHSN surveillance criteria for ventilator-associated events, the incidence rate of VAP was 24.4 per 1 000 ventilator days (95% *CI*: 12.8-46.5), with 64 (79.0%) patients requiring mechanical ventilation during the study period[16]. 64 (79.0%) patients were mechanically ventilated. Mean duration of mechanical ventilation was 5.7±3.0 days. Median duration of mechanical ventilation was 6 (IQR: 4-7) days. The duration range of mechanical ventilation was 2-20 days. Duration of mechanical ventilation was significantly associated with VAP in our study. The study findings indicate a significant association between the duration of mechanical ventilation and the incidence of VAP. With a total of 369 ventilator days and an incidence rate of 24.4 per 1 000 ventilator days (95% *CI*: 12.8-46.5), the data suggests that prolonged mechanical ventilation increases the risk of VAP.

3.4. Bacterial isolates in HAIs and antimicrobial susceptibility

Among the 12 patients with HAIs, the specimens from the majority of patients (n=9) were respiratory secretions (tracheal aspirate), whereas blood cultures were positive in three patients, as seen in Table 2. Of the 12 isolated pathogens, 75% (9 isolates) of HAIs were attributed to tracheal aspirates, among which *Klebsiella (K.) pneumoniae* was observed in 6 cases (50.0%), and *Acinetobacter (A.) lwoffii*, *Escherichia (E.) coli* , and Methicillin-Resistant *Staphylococcus (S.) aureus* (MRSA) were each isolated in 1 case (8.3%), respectively.

VAP was observed in 9 patients. The antimicrobial susceptibility profile of the isolates is shown in Table 3. Apart from 9 episodes of VAP, 3 episodes of HAIs were identified from blood cultures from central lines contributing to 3 cases of CLABSIs. The antimicrobial susceptibility profile of the isolates is shown in Table 4.

Table 1. Comparison of clinical characteristics between patients with and without HAIs.

Characteristics	HAIs present (n=12)	HAIs absent (n=69)	P
Age, years	51.2±13.4	46.4±17.0	0.36
Male [n (%)]	6 (50.0)	38 (55.1)	0.10
Hospital stay, days	7.6±4.1	5.8±2.9	0.07
Central line insertion [n (%)]	3 (25.0)	69 (100)	1.00
Duration of central line, days	7.6±4.1	5.6±3.1	0.06
Urinary catheter insertion [n (%)]	11 (91.7)	61 (88.4)	0.11
Duration of urinary catheter, days	7.8±4.2	6.1±2.9	0.10
Mechanical ventilation [n (%)]	9 (75.0)	55 (79.7)	0.89
Duration of mechanical ventilation, days	7.5±4.5	5.4±2.4	0.04
Mortality [n (%)]	4 (33.3)	15 (21.7)	0.54

Note: $P<0.05$ was considered statistically significant. Data are expressed as Mean±SD unless otherwise specified.

Table 2. Isolates according to type of specimens (n=12).

Source	Isolates	HAIs [(n (%)]
Tracheal aspirate	*Klebsiella pneumoniae*	6 (50.0)
	Acinetobacter lwoffii	1 (8.3)
	Escherichia coli	1 (8.3)
	Methicillin resistant *Staphylococcus aureus*	1 (8.3)
Blood from central line	*Pseudomonas aeruginosa*	2 (16.7)
	Acinetobacter lwoffii	1 (8.3)

Table 3. Antimicrobial susceptibility of ventilator-associated pneumonia (VAP) isolates: Sensitive (S) *vs*. Resistant (R) [*n*(%)].

Antimicrobials	Pattern	*Klebsiella pneumoniae*	*Escherichia coli*	*Acinetobacter lwoffii*	MRSA
Ampicillin	S	0 (0)	1 (100)	0 (0)	0 (0)
	R	6 (100)	0 (0)	1 (100)	1 (100)
Gentamicin	S	1 (16.66)	1 (100)	0 (0)	1 (100)
	R	5 (83.33)	0 (0)	1 (100)	0 (0)
Ciprofloxacin	S	2 (33.33)	1 (100)	0 (0)	0 (0)
	R	4 (66.67)	0 (0)	1(100)	1(100)
Trimethoprim-sulfamethoxazole	S	1 (16.66)	0 (0)	0 (0)	1 (100)
	R	5 (83.33)	1 (100)	1 (100)	0 (0)
Piperacillin-tazobactum	S	1 (16.66)	0 (0)	0 (0)	1 (100)
	R	5 (83.33)	1(100)	1 (100)	0 (0)
Ertapenem	S	1 (16.66)	1(100)	0 (0)	0 (0)
	R	5 (83.33)	0 (0)	1 (100)	1 (100)
Meropenem	S	1 (16.66)	0 (0)	1(100)	0 (0)
	R	5 (83.33)	1 (100)	0 (0)	1 (100)
Imipenem	S	1 (16.66)	0 (0)	0 (0)	0 (0)
	R	5 (83.33)	1 (100)	1 (100)	1 (100)
Amikacin	S	4 (66.67)	1 (100)	0 (0)	1 (100)
	R	2 (33.33)	0 (0)	1 (100)	0 (0)
Colistin	S	6 (100)	1 (100)	1 (100)	1 (100)
	R	0 (0)	0 (0)	0 (0)	0 (0)

Note: MRSA: Methicillin-resistant *Staphylococcus aureus*.

Table 4. Antimicrobial susceptibility of blood isolates: Sensitive (S) *vs*. Resistant (R) [*n* (%)].

Antimicrobial	Pattern	*Pseudomonas aeruginosa*	*Acinetobacter lwoffii*
Ampicillin	S	0 (0)	0 (0)
	R	2 (100)	1 (100)
Gentamicin	S	1 (50)	0 (0)
	R	1 (50)	1 (100)
Ciprofloxacin	S	2 (100)	0 (0)
	R	0 (0)	1 (100)
Trimethoprim-sulfamethoxazole	S	0 (0)	0 (0)
	R	2 (100)	1 (100)
Piperacillin-tazobactum	S	1 (50)	0 (0)
	R	1 (50)	1(100)
Ertapenem	S	0 (0)	0 (0)
	R	2 (100)	1(100)
Meropenem	S	1 (50)	0 (0)
	R	1 (50)	1 (100)
Imipenem	S	1 (50)	1 (100)
	R	1 (50)	0 (0)
Amikacin	S	2 (100)	0 (0)
	R	0(0)	1 (100)
Colistin	S	2 (100)	1 (100)
	R	0 (0)	0 (0)

4. Discussion

While HAIs surveillance systems are in place at national/sub-national level in many developed countries, only 23 developing countries (23/147) reported a functioning national surveillance system, according to a survey conducted by the WHO. Hospital-wide prevalence of HAIs varied from 5.7% to 19.1% with a pooled prevalence of 10.1 per 100 patients (95% *CI* 8.4-12.2) and most studies reported proportions of infected patients higher than 10%; the pooled prevalence of affected patients was 10.2 per 100 patients (95% *CI* 9.0-13.0)[10]. In an Indian study of 1 800-bedded tertiary care hospital, the overall prevalence of HAIs was observed to be 7%, among which surgical site infections were the most common (33%)[17].

In another multicentric study conducted at twelve Indian intensive care units, the overall rate was found to be 9.06 HAIs per 1 000 intensive care days, which is close to the global average in high income countries[18]. However, there is considerable variability in infection rates at institutions across the country. In this study, the HAIs was found to be 14.8% which has been correlated to previous studies.

In this study, VAP was observed in nine patients (11.1%) of the study population. The incidence rate of VAP was 24.4 per 1 000 ventilator days (95% *CI*: 12.8-46.5), as defined CDC/NHSN definition[16]. The duration of mechanical ventilation is a well-established risk factor for VAP, as prolonged ventilation increases the likelihood of bacterial colonization in the lower respiratory tract, impairs mucociliary clearance, and disrupts normal host defense mechanisms. In this study, patients who developed VAP had a significantly longer duration of mechanical ventilation compared to those who did not. These findings underscore the importance of early weaning strategies, strict adherence to ventilator care bundles, and infection control measures to minimize VAP risk in mechanically ventilated patients. In a study done in India, it was observed that the underlying VAP cases can increase due to trauma with higher percentage of 57.14%[19] and higher incidence density of about 31.7/1 000 ventilator days[20]. Duration of mechanical ventilation was significantly associated with VAP. In a study conducted by Ghosh *et al*. at a tertiary level ICU in New Delhi to evaluate the incidence, clinical profile, microbial etiology and antibiotic susceptibility, the VAP rates were observed to be 6.242/1 000 ventilator days with high mortality of 61.74%[21]. According to a systematic review on VAP of 20 years among ICU patients, the VAP rates were found to be 2.13 to 116 per 1 000 days with significant mortality from 16.2% to 74.1%[10].

In patients with VAP, Gram-negative organisms like *Acinetobacter* spp., *P. aeruginosa* and *K. pneumoniae* and Gram-positive organisms like *S. aureus* and Enterococcus species were frequently found[22]. The most common organisms in VAP patients were *Acinetobacter baumannii* (37.63%) and *K. pneumoniae* (36.55%) followed by *Pseudomonas* (*P.*) *aeruginosa* and *S. aureus*. The increase in multidrug-resistant (MDR) microorganisms triggering infections is growing worldwide and becoming more serious in developing countries[23,24]. In this study, *K. pneumoniae* was observed in 6 (50.0%) patients. *A. lwoffii*, *E. coli* and MRSA were each isolated in 1 patient (8.3%) confirmed with VAP. However, there was no significant difference in mortality between patients with VAP and without VAP.

In our study, the duration of mechanical ventilation was

significantly higher in patients with VAP compared to those without VAP (7.5±4.5 *vs*. 5.4±2.4 days, *P*=0.04). This was expected as patients with VAP are likely to be on the ventilation for longer duration and need higher antibiotics for a much longer time.

Central line was inserted in all 81 (100%) patients. 3.7% (3/81) CLABSIs were observed in the study population. There had been urinary catheter which was inserted 72 (88.9%) patients. No episode of CAUTIs was observed in the enrolled population. Non-occurrence of CAUTIs in our study signifies the good hand hygiene practices and adherence to standard protocols followed against HAIs in MICU in this study. Data from other institutions suggest a very high incidence of CAUTIs[10]. In a prospective observational study by Singhal et al. in Mumbai (India) from 2011 to 2018 at the adult, paediatric and neonatal ICU) of tertiary care private hospital, six hundred and eighty-six episodes of CLABSIs were recorded, and the overall incidence of CLABSIs was 5/1 000 central line days, 4.1 in the adult ICU, 5 in the paediatric ICU and 9 in the newborn ICU[25] which is similar to this study in which CLABSIs was observed to be 4/1 000 central line days in 3 positive patients admitted in MICU .

Data from our study suggested a high prevalence of carbapenem resistance in the isolates. Among 6 isolates, 83.33% of *K. pneumoniae* were ertapenem resistant (5 out of 6 isolates). All the isolates were susceptible to colistin. Carbapenem resistance is increasingly being found in isolates from the ICUs all over the world. This is an alarming situation as carbapenems are the mainstay of antimicrobial therapy in critically ill patients.

Among blood samples in our study, imipenem and meropenem resistance in *P. aeruginosa* was found to be 50% whereas ertapenem was found to be 100% resistant. A study by Gladstone *et al*. concluded that 12.2% of the 460 non-fermenting Gram-negative bacilli (NFGNB) were found to be resistant to carbapenems[26]. Of these, 24 (42.8%) were *P. aeruginosa*, 8 (14.2%) were *Acinetobacter* spp. and 24 (42.8%) were other NFGNB. Jaggi N *et al* also evaluated the carbapenem resistance rate and prevalence of different carbapenemase genes in *K. pneumoniae* and *E. coli* at a North Indian corporate hospital that received both Indian and international patients[27]. Indian Council of Medical Research network data also reported an increasing prevalence of NFGNB causing HAIs. Treatment of multi drug resistance (cephalosporin, carbapenems, aminoglycosides and quinolones) and pan-drug resistance in NFGNB is a real challenge to the treating intensivist. This data from Indian Council of Medical Research corroborates to our data which shows a glaring carbapenem resistance in isolates[28]. Resistance mechanisms such as carbapenemase production are associated with increased virulence and transmission risks, further complicating infection control efforts. To reinforce these findings, the study by Jwair *et al*. highlights the inverse association between CRISPR/Cas systems and antibiotic resistance, including carbapenemase production in multidrug-, extensively drug-, and pandrug-resistant *K. pneumoniae* strains. The presence of CRISPR/Cas systems may play a role in limiting the spread of resistance genes, suggesting potential future therapeutic and preventive strategies[29]. Infection control practices need to be strengthened and surveillance (passive as well as active) is needed to generate data on the prevalence and pattern of antimicrobial resistance. The limitation of our study is that patients were enrolled only from MICU and not from other ICUs like surgical *etc*. and this period coincides with the COVID-19 outbreak. Therefore, our findings may not be representative of other specialties.

5. Conclusions

This study highlights the incidence of HAIs in critically ill ICU patients and the concerning rise of carbapenem resistance in HAI-causing pathogens. The findings provide essential baseline data to guide infection control practices and antimicrobial stewardship efforts. Although no cases of CAUTIs were observed, VAP remained the predominant HAIs, emphasizing the need for improved ventilator care strategies and MICU aseptic protocols. The high prevalence of carbapenem-resistant *K. pneumoniae* and other multidrug-resistant pathogens underscores the urgency of implementing stricter infection prevention and control measures. Future studies should focus on multicenter surveillance to better understand resistance trends, evaluate the effectiveness of novel antimicrobial therapies, and assess the role of rapid diagnostic tools in early detection of resistant infections. Additionally, research on alternative therapeutic approaches, such as bacteriophage therapy or clustered regularly interspaced short palindromic repeats-based resistance control, may provide new avenues for combating antimicrobial resistance in ICU settings.

Conflict of interest statement

The authors declare that there is no conflict of interest.

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Data availability statement

The data supporting the findings of this study are available from the corresponding author upon request.

Authors' contributions

William A, Randhawa VS, Kaur R, and Pangtey GS conceived the idea for the study. Kumar A, Randhawa VS, and William A were involved in data collection, cleaning, and analysis, writing the first draft, review and editing. Kumar A and William A had full access to the study data and acted as guarantor. William A, Kumar A, Randhawa VS, Kaur R, and Pangtey GS were involved in data cleaning, statistical analysis, review, editing and overall study coordination. All authors provided technical inputs to the manuscript and approved the final version of the paper.

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