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Evaluating the outcome of a bundle with 11 components and the INICC multidimensional approach in decreasing rates of central line-associated bloodstream infections across nine Asian countries

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Abstract

Background: Central line-associated bloodstream infection (CLABSI) rates in intensive care units (ICUs) across Latin America exceed those in high-income countries significantly.

Methods: We implemented the INICC multidimensional approach, incorporating an 11-component bundle, in 122 ICUs spanning nine Asian countries. We computed the CLABSI rate using the CDC/NSHN definition and criteria. The CLABSI rate per 1000 CL-days was calculated at baseline and throughout different phases of the intervention, including the 2nd month, 3rd month, 4–16 month, and 17–29 month periods. A two-sample *t*-test was employed to compare baseline CLABSI rates with intervention rates. Additionally, we utilized a generalized linear mixed model with a Poisson distribution to analyze the association between exposure and outcome.

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Results: A total of 124,946 patients were hospitalized over 717,270 patient-days, with 238,595 central line (CL)-days recorded. The rates of CLABSI per 1000 CL-days significantly decreased from 16.64 during the baseline period to 6.51 in the 2nd month (RR = 0.39; 95% CI = 0.36–0.42; $p < 0.001$), 3.71 in the 3rd month (RR = 0.22; 95% CI = 0.21–0.25; $p < 0.001$), 2.80 in the 4–16 month (RR = 0.17; 95% CI = 0.15–0.19; $p < 0.001$), and 2.18 in the 17–29 month (RR = 0.13; 95% CI = 0.11–0.15; $p < 0.001$) intervals. A multilevel Poisson regression model demonstrated a sustained, continuous, and statistically significant decrease in ratios of incidence rates, reaching 0.35 ($p < 0.0001$) during the 17–29 month period. Moreover, the all-cause in-ICU mortality rate significantly decreased from 13.23% to 10.96% ($p = 0.0001$) during the 17–29 month period.
Conclusions: Our intervention led to an 87% reduction in CLABSI rates, with a 29-month follow-up.

Keywords
Central line-associated bloodstream infections, bloodstream infection, limited resources countries, network, Asia, INICC

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Introduction

In medical surgical intensive care units (ICUs), the Center for Disease Control (CDC) and Prevention's National Healthcare Safety Network (NHSN) recorded a median rate of 0.8 central-line-associated bloodstream infections (CLABSI) per 1000 central line (CL)-days.[1] Data shows evidently that low and middle-income countries (LMICs) experienced higher CLABSI rates than the United States (US) according to the International Nosocomial Infection Control Consortium (INICC).[2–5] A comprehensive review highlighted that CLABSI rates varied widely, ranging from 1.6 to 44.6 per 1000 CL-days in adult ICUs and 2.6 to 60.0 in neonatal ICUs.[4]

Mortality in ICU patients without healthcare associated infection (HAIs) is 14.06%, while the ones with CLABSI is 39.81%, and furthermore those with CLABSI combined with ventilator associated pneumonia (VAP) and catheter associated urinary tract infections (CAUTI) is 46.56%.[5] In previous study in 786 ICUs across 37 countries, CLABSI independently increased in-ICU all-cause mortality,[6] confirmed in Asian,[7] and Middle Eastern countries.[8] CLABSI rates also impact healthcare by raising costs.[9]

Public health hinges on essential initiatives to decrease CLABSI rates. Directives spanning from the 1996 Hospital Infection Control Practices Advisory Committee (HICPAC) recommendations,[10] to the 2022 guidelines by the Infectious Diseases Society of America (IDSA), Society for Healthcare Epidemiology of America (SHEA), and Association for Professionals in Infection Control and Epidemiology (APIC),[11] provide evidence-based approaches. Michigan hospitals effectively employed Pronovost et al.'s[12] comprehensive bundle with five components to reduce CLABSI rates.

CLABSI occurrences in LMICs countries surpass those in the US, with rates of 4.55 CLABSI per 1000 CL-days,[5] opposed to 0.80.[1] We investigated the decreasing CLABSIs and in-ICU all-cause mortality in Asian countries by merging 11 evidence-based interventions,[10,11] utilizing the INICC multidimensional approach (IMA, described below). This research intends to evaluate the impact of interventions based on these recommendations for a duration of up to 29 months following implementation.

Methods

Setting and participants

The data were gathered from 122 ICUs in 61 institutions across 25 Asian cities in nine countries: China, India, Malaysia, Mongolia, Nepal, Pakistan, the Philippines, Thailand, and Vietnam. Various ICU categories are listed in Table 1. Table 1 shows the proportions of hospitals, stratified as for-profit, public, teaching, and non-profit, as well as nations stratified into upper middle income and lower middle income.

Study definitions

Health care associated infection. HAI definitions used during surveillance were those published by CDC in 1991,[13] and all their subsequent updates.[14] All IPPs of all participant hospitals have been applying the current and updated CDC/NHSN definition of HAIs. That is, whenever the CDC updated their definitions, our IPPs began using the new updated definitions.[13,14] Definitions of central line, central line-associated bloodstream infection, laboratory-confirmed bloodstream infection 1, and laboratory-confirmed bloodstream infection 2 are those published by CDC/NHSN.[13,14]

International Nosocomial Infection Control Consortium (INICC)

INICC, a global network of infection prevention professionals (IPPs), aims to reduce fatalities, bacterial resistance, hospital stays, and HAI-related costs, including CLABSIs. It establishes uniform HAI surveillance protocols, collaborates on guidelines with governments, fosters

Table 1. Setting and patient characteristics.

ICUs, *n*	122
Hospitals, *n*	61
Cities, *n*	25
Countries, *n*	9
Total patients, *n*	124,946
Total patients-days, *n*	717,270
Gender, *n* (%)	
Male	77,009 (61.63%)
Female	47,937 (38.37%)
Age, mean, SD	54.18, SD = 22.15
Average LOS, mean, SD	Mean = 2.18, SD = 7.17
CLABSI, *n*	1181
Device-days and device utilization ratio	
CL-DU ratio, mean, SD	Mean = 0.47, SD = 1.47
Total CL-days, *n*, mean, SD	Total = 238,595, mean = 1.91, SD = 7.41
Survival status, *n* (%)	
Alive	112,295 (89.87%)
Death	12,651 (10.13%)
Number of patients per hospitalization type	
Medical hospitalization, *n* (%)	99,026 (79.26%)
Surgical hospitalization, *n* (%)	25,920 (20.74%)
Number of patients admitted per type of ICU, *n* (%)	
Cardio-thoracic ICU	2744 (2.20%)
Coronary ICU	5080 (4.07%)
Medical ICU	22,884 (18.32%)
Medical-surgical ICU	72,899 (58.34%)
Neuro-surgical ICU	4732 (3.79%)
Neurologic ICU	1373 (1.10%)
Adult-oncology ICU	46 (0.037%)
Pediatric-oncology ICU	17 (0.014%)
Pediatric ICU	5753 (4.60%)
Surgical ICU	7127 (5.70%)
Trauma ICU	2291 (1.83%)
Number of patients admitted per facility ownership, *n* (%)	
Publicly owned facilities	13,772 (11.02%)
For-profit privately owned facilities	64,692 (51.78%)
Teaching hospitals	36,091 (28.89%)
Not-for-profit privately owned facilities	10,391 (8.32%)
Number of countries, stratified per income level according to World Bank, *n* (%)	
Lower middle income country	6 (66.67%)
Upper middle income country	3 (33.33%)

ICU: intensive care unit; CL: central line; DU: device utilization; LOS: length of stay; CLABSI: central line associated bloodstream infection; SD: standard deviation; CI: confidence interval.

knowledge exchange, supports HAI research, educates healthcare workers, advocates for evidence-based literature on HAI surveillance, and conducts studies to assess intervention impact.[15]

International Nosocomial Infection Control Consortium Surveillance Online System (ISOS)

INICC Surveillance Online System (ISOS), an online tool, follows CDC/NHSN standards for HAI tracking.[14] ISOS collects patient data for all admissions, including HAI status. IPPs use tablets connected to ISOS for daily ICU patient recording, from admission to discharge. Data, such as country, city, ICU type, admission date, and patient details (sex, age, hospitalization), is inputted upon admission. IPPs update device usage, CL duration, LOS, positive cultures data, CLABSIs, and in-ICU all-cause mortality until discharge. Hospital IPP teams verify cultures before uploading to ISOS. CLABSI rates are calculated as CLABSI per 1000 CL-days for each period.[15] The study received approval from collaborating hospitals' Institutional Review Boards, ensuring anonymity for hospitals and patients.

International Nosocomial Infection Control Consortium multidimensional approach (IMA)

The IMA represents a global ICU patient safety effort involving the simultaneous adoption of six CLABSI prevention elements: (1) a comprehensive bundle containing 11 evidence-based infection prevention practices; (2) education about the bundle's content; (3) tracking CLABSI and associated clinical results; (4) fidelity monitoring; (5) providing information on HAI rates and linked clinical outcomes; and (6) offering performance-related feedback. Every hospital involved with INICC embraced the IMA.[15]

Bundle of infection prevention practices

1. Adhere to hand hygiene before catheter insertion or manipulation.[11]
2. Use maximal sterile barrier precautions during catheter insertion.[11]
3. Apply alcoholic chlorhexidine antiseptic for skin preparation.[11]
4. Preferring non-femoral sites over femoral site.[11,16–18]
5. Eliminate unnecessary catheters, reducing catheter days.[11,16–18]
6. Maintain proper insertion site dressing, changing when loose, wet, dirty, or bloody.[19–21]
7. Minimize LOS by promptly discharging eligible patients.[16–18]
8. Daily chlorhexidine bathing for ICU patients aged >2 months.[11]
9. Prioritize needle-free connectors (NFCs) over three-way stopcocks as NFCs are linked to lower CLABSI rates by literature.[22,23]
10. Prioritize collapsible closed IV fluid systems (CCIVFS) over semi-rigid open systems as CCIVFS are linked to lower CLABSI rates by literature.[24–26]
11. Prioritize single-use flushing (SUF) over manual admixture as SUF are linked to lower CLABSI rates by literature.[22]

Education

Before the study began, INICC's research team held three 1-h webinars to educate IPPs about each bundle item and its implementation. Following that, IPPs conducted three live hour-long hospital sessions to instruct HCWs on the 11 bundle components.[15]

Surveillance of central line-associated bloodstream infections and clinical outcomes

Ongoing, proactive monitoring via ISOS employing CDC/NHSN definitions spanning from 1991,[13] to the present.[14]

Implementation fidelity monitoring

ISOS modules facilitated the monitoring of implementation fidelity, ensuring adherence to the CLABSI preventive components of the INICC bundle.[15]

Feedback on healthcare associated infection rates and consequences

IPPs use ISOS to produce monthly reports that include CLABSI rates and outcomes. These reports feature charts and tables summarizing patient characteristics, HAI rates (e.g. CLABSI, VAP, CAUTI), device utilization ratios (DURs), microorganism data, resistance patterns, LOS, and in-ICU all-cause mortality. These metrics are compared to CDC/NHSN rates,[1] for benchmarking purposes, to INICC's 45-country report,[3] and country-specific INICC reports such as India,[27] Mongolia,[28] Philippines,[29] Vietnam,[30] and China.[31]

Performance feedback

IPPs, in monthly meetings, provide performance feedback to HCWs by presenting implementation fidelity monitoring outcomes. They use ISOS-generated charts to highlight HCW compliance with intervention components. This approach enables attending HCWs to recognize improvement opportunities when compliance rates are low, leveraging the "observer effects" to influence HCW behavior and enhance practice effectiveness, facilitating improvements.[32]

The intervention

Since 2003, hospitals have joined INICC by appointing at least one IPP to manage INICC-related matters before enrollment. Upon enrollment, hospitals start using ISOS for CLABSI monitoring and assessing compliance with infection prevention recommendations. In the second month, they introduce the IMA. IPPs receive guidance from INICC's team on implementing interventions and receive evidence of their effectiveness.[15]

Hospitals commence ISOS implementation at baseline for CLABSI monitoring, patient data collection, and tracking compliance. As not all participating countries started at the same time, we normalized the data from those first months to align with the first month of the baseline, the second month, the third month, and so on. In this study, hospitals from India began participating in January 2008, followed by China in July 2009, the Philippines in December 2009, Malaysia in January 2014, Vietnam in December 2014, Mongolia in March 2015, Sri Lanka in August 2016, Nepal in March 2016, and Pakistan in November 2016. All 11 procedures commence with patients in the second month, which is the initial month of

intervention.[15] The emphasis is on 11 impactful, uncomplicated evidence-based practices for reducing CLABSI, with a strong focus on HCW adherence.[10–12]

The daily rounds focus on the implementation of rigorous hand hygiene before CL procedures, using maximum sterile barrier precautions, employing alcoholic chlorhexidine for skin preparation, avoiding the femoral site, eliminating unnecessary CLs, minimizing CL-days, maintaining proper insertion site dressings, and ensuring timely discharge of eligible patients, daily chlorhexidine bathing for ICU patients aged >2 months, prioritizing needle-free connectors, collapsible closed IV fluid systems, and single-use prefilled syringe flush systems.

Monthly meetings deliver updates to attending HCWs on CLABSI rates, extended LOS, supplementary expenses, in-ICU all-cause mortality, and adherence to the infection prevention components of the intervention bundle.[15]

Measurement and categorization of data

Comparing baseline and intervention groups, we examined patient characteristics and infection prevention adherence using hospital-collected CLABSI and CL-day data. Data were collected at different time points: baseline month, second and third intervention months, months 4–16, and months 17–29. Monthly CLABSI rates were calculated for each period without additional interventions. We assessed patient variables, including device usage, HAIs, length of stay (LOS), and in-ICU all-cause mortality.[15]

Across baseline and intervention, we assessed HCWs' adherence to: (1) hand hygiene before catheter insertion/manipulation[11]; (2) maximal sterile barrier during CL insertion[11]; (3) alcoholic chlorhexidine for skin prep[11]; (4) prioritize non-femoral sites, increase subclavian, jugular, PICC usage[11,16–18]; (5) remove nonessential catheters, lower CL-days[11,16–18]; (6) maintain a good condition of the dressing and changing it when it is either loose dirty or stained with blood[19–21]; (7) shorten LOS and discharge promptly whenever possible[16–18]; and (8) improve adherence to the use of single use prefilled syringe for flushing.[22]

Exposure, outcomes, and study hypotheses

We used four categorical time variables to assess exposure to the research intervention, comparing values to the baseline to gauge its effectiveness after full implementation. Our study focused on two outcomes: the CLABSI rate and in-ICU all-cause mortality rate. Our primary research hypothesis predicted that implementing the study's intervention, which included IMA and an 11-component bundle, would result in reduced CLABSI and in-ICU all-cause mortality rates compared to baseline. We also hypothesized that the initial decline in CLABSI rates observed in the first month after the intervention would persist throughout the subsequent 29-month observation period. Notably, we did not individually evaluate the efficacy of the 11 components.

Statistical analysis

A two-sample *t*-test was used to compare baseline CLABSI rates with intervention rates. We employed a generalized linear mixed model,[33,34] with a Poisson distribution for modeling the number of CLABSIs in order to investigate the association between exposure and outcome. To account for nested clustering in the data of CLABSI rates within hospitals and hospitals within the world bank classification of economies (i.e. low-income, lower-middle, upper-middle, and high), we utilized robust variance estimation and added two-level random effects in the model.[33,34] In the model, we adjusted for the ownership type of the facility (public, private, academic, or nonprofit).

To evaluate and contrast the patient characteristics in the baseline and intervention groups, we employed relative risk ratios, 95% confidence intervals, and the accompanying *p*-values. To compare the degree of compliance with infection prevention recommendations between the baseline group and the intervention group, we employed relative risk ratios, along with 95% confidence intervals and their corresponding *p*-values. Using the Exact Poisson method and the exact mid-*p* double sided *p*-value, we compared the relative risk of CLABSI rates and in-ICU all-cause mortality rates during intervention with baseline. The Wilcoxon rank-sum test was used to compare the average length of stay during intervention to baseline. All reported *p* values were two-sided, and we considered a *p* value of.05 or less to be statistically significant. For the analysis, we used R program (version 4.2.3).

The study received approval from the institutional review boards of the participating hospitals. Since the study was deemed exempt from review, obtaining informed consent was not necessary. The authors, who had full access to the data, ensure the accuracy and completeness of both the data and the analysis.

Results

Table 1 shows that 124,946 patients contributed to 717,270 patient days and 238,595 CL days. Patient characteristics remained similar for both medical and surgical hospitalization types, with a higher proportion of men (61.63% vs 38.37%). Patients during the intervention were older compared to the baseline, but the use of tracheostomy and hospitalization type were similar (see Table 2).

During the intervention, significant changes included increased chlorhexidine skin antisepsis (90.91%–93.55%), more jugular insertions (29.52%–36.27%), greater use of single-use prefilled syringe flush (57.82%–94.55%), reduced CL dwell time (from 2.45 to 1.90 CL-days), and

Table 2. Comparison of patients characteristics among baseline and intervention period.

	Baseline (month 1)	Intervention (months 2nd–29th)	RR	95% CI	*p* Value
Gender, *n* (%)					
Male	781/1227 (63.65%)	76,228/123,719 (61.61%)	0.97	(0.94, 0.99)	0.04
Female	446/1227 (36.35%)	47,491/123,719 (38.39%)	1.06	(1.02, 1.09)	<0.0001
Age, mean, SD	Mean = 49.1, SD = 23.08	Mean = 54.23, SD = 22.14	1.11	(1.08, 1.13)	<0.0001
Total patients, *n*	1227	123,719			
Total patients-days, *n*	8307	708,963			
CLABSIs, *n*	34	1147			
Number of patients per hospitalization type, *n* (%)					
Medical hospitalization, *n* (%)	992/1227 (80.85%)	98,034 (79.24%)	0.98	(0.96, 1.00)	0.37
Surgical hospitalization, *n* (%)	235/1227 (19.15%)	25,685 (20.76%)	1.08	(1.04, 1.13)	0.03
Tracheostomy use, *n* (%)	13/1227 (1.06%)	1063/123,719 (0.86%)	0.81	(0.65, 1.01)	0.05

ICU: intensive care unit; CL: central line; DU: device utilization; LOS: length of stay; CLABSI: central line associated bloodstream infection; SD: standard deviation.

Table 3. Comparison of compliance with recommendations to prevent CLABSI.

Intervention	Baseline (month 1)	Intervention (month 2–29)	RR	95% CI	*p* Value
Hand hygiene compliance, *n* (%)	1316/1772 (74.27%)	49,109/65,319 (75.18%)	1.01	(0.98, 1.04)	0.89
Max precaution barrier, *n* (%)	375/380 (98.68%)	30,587/30,816 (99.26%)	1.01	(0.99, 1.03)	0.74
Chlorhexidine skin antisepsis, *n* (%)	380/418 (90.91%)	29,071/31,077 (93.55%)	1.03	(1.01, 1.05)	0.04
Number of CL-days per type of CL, *n* (%)					
Femoral	212 (7.04%)	16,130 (6.85%)	0.97	(0.91, 1.05)	0.09
Jugular	889 (29.52%)	85,457 (36.27%)	1.23	(1.19, 1.27)	<0.0001
Subclavian	1866 (61.95%)	130,844 (55.54%)	0.89	(0.87, 0.92)	<0.0001
Hemodialysis temporary	27 (0.90%)	1643 (0.70%)	0.78	(0.61, 0.98)	<0.0001
PICC	18 (0.59%)	1509 (0.64%)	1.08	(0.84, 1.39)	0.22
Catheter necessary, yes, *n* (%)	424/427 (99.30%)	38,600/38,728 (99.67%)	1.00	(0.98, 1.02)	0.89
Single use flushing	85/147 (57.82%)	26,389/27,911 (94.55%)	1.63	(1.61, 1.67)	<0.0001
CL-days (dwelling time), mean, SD	3012, mean = 2.45, SD = 6.37	235,583, mean = 1.90, SD = 7.96	0.78	(0.67, 0.89)	<0.0001
Good condition of dressing, *n* (%)	448/465 (96.34%)	38,451/39,866 (96.45%)	1.00	(0.98, 1.02)	0.79
Average LOS, mean, SD	Mean = 6.77, SD = 10.83	Mean = 5.73, SD = 7.03	0.85	(0.78, 0.92)	0.01

CL: central line; LOS: length of stay.

shorter LOS (from 6.77 to 5.73 days). Femoral CL usage decreased slightly (7.04%–6.85%), while PICC line usage remained consistent (0.59%–0.64%). Maximal barrier usage (98.68% and 99.26%), well-maintained dressings (96.34% and 96.45%), and hand hygiene (74.27%–75.18%) remained high in both periods (see Table 3).

A significant reduction in CLABSI rates per 1000 CL-days was observed, starting at a baseline of 16.64 and decreasing to 6.51 in the second month, 3.71 in the third month, 2.80 from months 4 to 16, and 2.18 in months 17 to 29 (see Table 4). The incidence rate ratios consistently decreased, ranging from 0.51 in the second month to 0.35 in months 17 to 29 following the study's implementation, as indicated in the multilevel Poisson regression model (see Table 4). In-ICU all-cause mortality decreased significantly from 13.23% to 10.96% during months 17–29 after the study's implementation (see Table 4).

Discussion

The primary goal of the INICC project was to enhance patient safety in Asia, achieved by lowering CLABSI rates through the ISOS platform, IMA, and an 11-component bundle. This initiative encompassed 122 ICUs across nine Asian countries and formed the foundation of the analysis. CLABSI rates showed a significant decline from 16.64 to 6.51 during the initial month of intervention, sustaining the downward trend to 2.18 between months 17 and 29. This significant 87% reduction in CLABSI rates remained consistent across hospitals.

This study illustrates the feasibility and potential impact of a large-scale effort to reduce CLABSI occurrences. In previously published research, a significant reduction in infection rates was already achieved. However, even after these rates have been reduced, in adult,[19] pediatric,[21] and neonatal ICUs,[20] they have never reached levels as low as

Table 4. Number of countries, cities, hospitals, ICUs, patients, patient-days, CLABSI rate, incidence rate ratio, and mortality rate, comparing baseline with intervention periods, with 29 months follow up.

Number of countries, cities, hospitals, ICUs, patients, and patient-days comparing baseline with intervention periods

Study period	Countries, *n*	Cities, *n*	Hospitals, *n*	ICUs, *n*	Patients, *n*	Patients-days, *n*
Baseline	9	25	61	122	3076	18,571
2nd month	9	25	61	122	3379	21,685
3rd month	9	22	53	115	2981	16,297
4th–16th mo	9	23	52	113	27,659	157,958
17th–29th mo	9	22	45	89	24,383	128,945

CLABSI rate, incidence rate ratio of CLABSI, and mortality comparing baseline with intervention periods

Study period	CL-days, *n*	CLABSIs, *n*	CLABSI rate[a] median (95% CI)	RR (95% CI)	*p*-Value	Incidence rate ratio (95% CI)	*p*-Value	Mortality rate, % (95% CI)	*p*-Value
Baseline	10,577	176	16.64 (16.56, 16.72)			1.00	NA	13.23% (12.53%, 13.96%)	
2nd month	10,293	67	6.51 (6.46, 6.56)	0.39 (0.36, 0.42)	<0.0001	0.51 (0.36, 0.72)	<0.0001	10.83% (10.19%, 11.49%)	0.0054
3rd month	9707	36	3.71 (3.67, 3.75)	0.22 (0.21, 0.25)	<0.0001	0.41 (0.21, 0.61)	<0.0001	11.30% (10.65%, 11.98%)	0.0324
4th–16th mo	113,351	317	2.80 (2.77, 2.81)	0.17 (0.15, 0.19)	<0.0001	0.39 (0.19, 0.59)	<0.0001	10.09% (9.48%, 10.73%)	<0.0001
17th–29th mo	101,126	220	2.18 (2.17, 2.19)	0.13 (0.11, 0.15)	<0.0001	0.35 (0.14, 0.57)	<0.0001	10.96% (10.32%, 11.63%)	0.001

mo: month; ICU: intensive care unit; CL: central line; CLABSI: central line associated bloodstream infection; CI: confidence interval.
[a]CLABSI rate per 1000 CL-days.

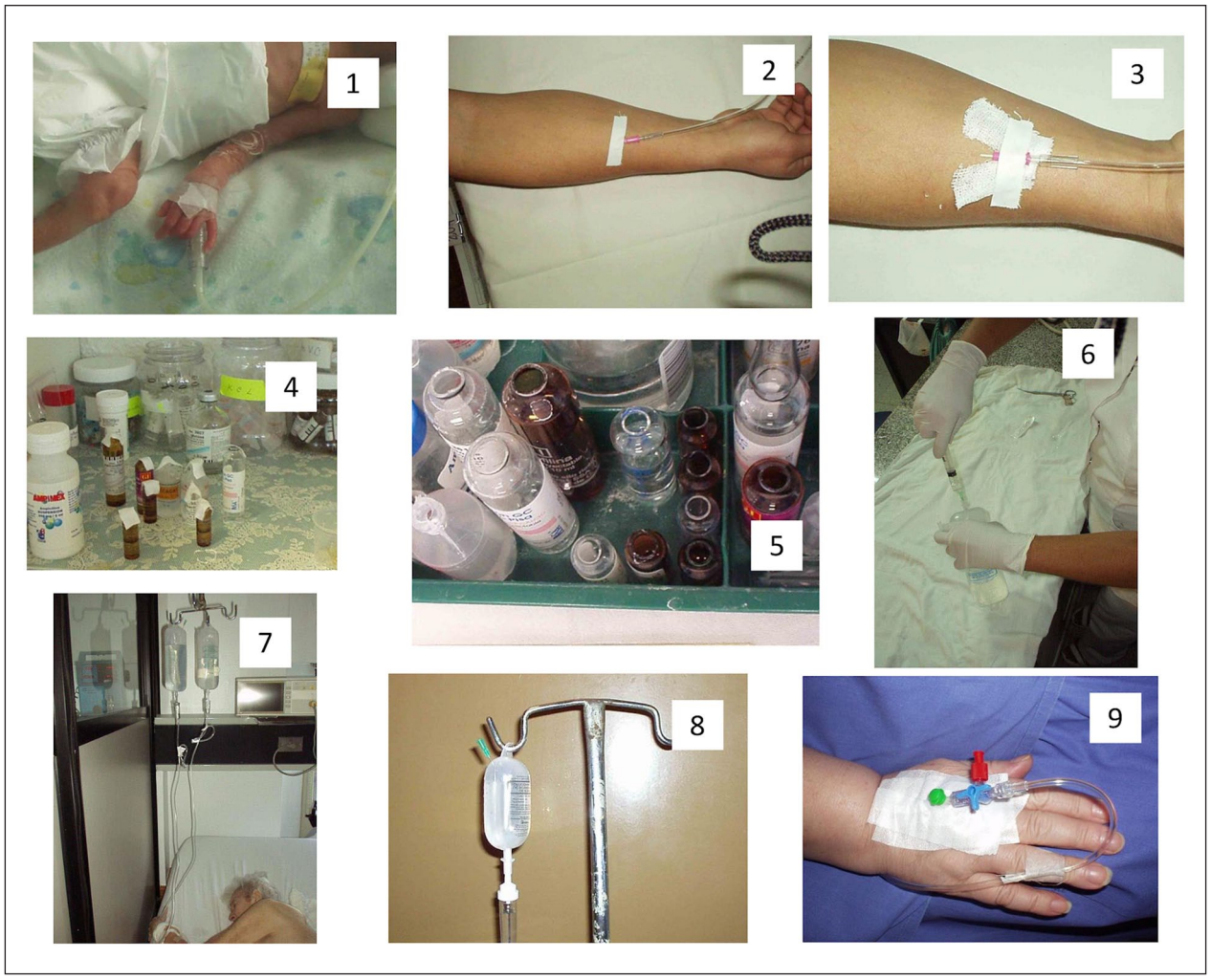


Figure 1. The process and supplies for vascular catheter care in low and middle-income countries of Asia.
Images 1, 2, and 3: Vascular catheter insertion site without sterile dressing; Images 4 and 5: Single-use vials are opened to the air and reused multiple times; Image 6: Manual admixture of IV fluid for flushing; Image 7 and 8: Open IV fluid container; Image 9: Three way stop cock.

those in high-resource countries until the implementation of our 11 component bundle.

Evaluating the impacts on patient safety in Asian countries proves intricate, aided by tools such as ISOS, IMA, and IPP teams, which facilitate monitoring CLABSI rates and bundle compliance. The findings suggest the possibility of lowering CLABSI rates globally, reducing in-ICU all-cause mortality, and cutting expenses. Notably, the intervention achieved these outcomes without incurring excessive costs or requiring additional staff. Implementing these measures could lead to enhanced clinical outcomes and cost efficiency, particularly considering the initial report of 176 CLABSIs.

It is crucial to highlight that in LMICs of Asia, the availability of resources significantly differs from that in high-income countries (see Figure 1). In future studies, it is advisable to integrate additional evidence-based interventions. These could encompass the utilization of ultrasound for the insertion of vascular catheters, modern sutureless devices, as well as adhesive agents designed to seal the exit site and prevent both bleeding and early colonization.[11] It is noteworthy that the current study did not incorporate these interventions due to their unavailability at the commencement of our research.

However, this study does have limitations. Directly attributing each component to the reduction in CLABSI rates is challenging due to the study's design. Challenges arose in selecting interventions due to demands in the ICU, leading to the absence of a control group. The independence of microorganism-outcome wasn't individually assessed. Potential underreporting may introduce bias, despite adherence to CDC/NHSN guidelines. The analysis focused solely on INICC network ICUs, which may impact generalizability. Additional data, including information on underlying diseases and severity of illness scores, would be needed to confirm the intervention's impact on in-ICU all-cause mortality. Although not conclusive, the reduction in CLABSI rates likely influenced in-ICU all-cause

mortality, given their interconnected nature. This suggests that lower CLABSI rates had a tangible effect on in-ICU all-cause mortality.

In summary, CLABSIs raise concerns regarding costs, LOS, and fatalities. Implemented across 122 ICUs in nine Asian countries, the intervention led to a substantial CLABSI rate reduction from 16.64 to 2.18 per 1000 CL-days, a notable 87% drop. Widespread implementation potential could alleviate CLABSI-related morbidity and financial strain.

Author contributions

Rosenthal, V.D. was responsible for conceptualization; data curation; formal analysis; investigation; methodology; project administration; resources; software; supervision; validation; visualization; writing original draft; review & editing; design; software development; technical support; drafting tutorials for surveillance process; training of data collectors; provision of study patients; data validation; data assembly; data interpretation; epidemiological analysis; drafting of the manuscript; search, and insertion of scientific references. Zhilin Jin and Ruijie Yin contributed equally to data curation; formal analysis; methodology; validation; writing original draft; review & editing; building machine learning models; conducting statistical analysis; critical revision for important intellectual content; and final approval of the manuscript. Remaining authors were involved in the provision of study patients. All authors were involved in critical revision of the manuscript for important intellectual content, and final approval of the manuscript.

Declaration of conflicting interests

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