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The Role of Nurses in Infection Prevention and Control: Post-COVID-19 Challenges and Practices in Iraqi Healthcare Systems

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ABSTRACT
Background: COVID-19 has had a significant impact on global health care, revealing significant deficiencies in infection prevention and control (IPC) systems and nursing capacities, especially in low- and middle-income settings like Iraq. Nurses are at the forefront of IPC implementation, but little is known about how the pandemic has long-term reshaped their knowledge, practices and the enabling factors in the Iraqi context. This study sought to compare IPC knowledge and practice adherence, healthcare-associated infection (HAI) prevalence and other barriers across three groups of nurses - pre-COVID, COVID-19 era, and post-COVID - in Iraq's hospitals. Methods: A cross-sectional multi-site design was used. A sample of 294 registered nurses from eight tertiary-care hospitals in Baghdad, Basra, Salah al-Din, and Kirkuk governorates were divided into three cohorts based on the time period of their data collection: Pre-COVID (n=97), COVID-Era (n=101), and Post-COVID (n=96). We used a validated IPC knowledge questionnaire, a World Health Organization (WHO)-compatible direct-observation practice assessment tool, and HAI surveillance data from participating hospitals. One-way ANOVA and Tukey post-hoc tests, and chi-squared tests were performed. Results: IPC composite knowledge scores improved significantly from Pre-COVID (52.4 ± 9.8) through COVID-Era (71.6 ± 8.4) to Post-COVID (81.3 ± 7.2) ($p<0.001$). Hand hygiene compliance rose from 61.4 ± 10.2% to 92.8 ± 5.7% ($p<0.001$). Overall HAI rates declined from 14.8 ± 3.6% to 5.9 ± 1.9% ($p<0.001$), with corresponding falls in CLABSI (4.8 to 1.6 per 1,000 device-days), VAP, CAUTI, and SSI rates. IPC fatigue was highest in COVID-Era (56.4%) and decreased post-pandemic (32.3%). Widespread availability of PPE rose from 38.1% to 91.7% ($p<0.001$). Conclusion: COVID-19 inadvertently provided the impetus for ongoing IPC improvements in Iraq's hospitals. There remain issues with staffing levels and fatigue, which highlight the need for structured strategies to consolidate and build on post-pandemic gains, and to focus on long-term workforce resilience in nursing.

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INTRODUCTION

Health-care-associated infections (HAIs) continue to be one of the most significant and costly adverse events in health care. HAIs occur in hundreds of millions of patients every year, extend the duration of hospital stay, contribute to the development of antibiotic-resistant superbugs and inflict enormous financial pressures on health budgets [1,2]. HAIs are more prevalent in low- and middle-income countries - estimates of HAI prevalence are two to three times higher than in high-income countries - due to suboptimal infrastructure, human resources, and uneven implementation of IPC policies [3,4].

Iraq's health-care system, which has recovered from decades of war, sanctions and infrastructure collapse, is a challenging environment for IPC [5]. Before 2020, research showed a lack of nurse IPC knowledge, the lack

of access to point-of-care hand hygiene products and insufficient isolation rooms in the public hospitals [6,7]. In this context, the arrival of SARS-CoV-2 in early 2020 put Iraqi health care facilities under unprecedented strain, while also highlighting vulnerabilities and prompting swift, if patchy, IPC infrastructure and practice improvements [8].

International evidence suggests the pandemic spurred major investments in PPE procurement, IPC training and surveillance [9,10]. A number of studies from high-income countries have reported significant decreases in HAI rates during the pandemic, which have in part been attributed to increased vigilance in IPC implementation, given the risk of SARS-CoV-2 transmission [11,12]. It is unclear whether these effects have endured in the post-pandemic era, and whether such effects are evident in resource-poor settings like Iraq [13].

Nurses play a key role in delivering IPC measures. Understanding transmission routes, proficiency in the use of standard and transmission-based precautions, and maintaining practice fidelity in different resource settings are all key to the success of IPC [14,15]. So, clarifying the impact of the COVID-19 experience on nurse IPC competencies and the dynamic environment in which these are supported is crucial for shaping post-pandemic health policy and curriculum reform in Iraq [16]. Existing research on Iraqi nurses and IPC has been narrow in focus, typically focusing on single hospitals, single types of infection, or single points in time, making it challenging to understand the pandemic's impact in relation to the broader trends in IPC capacity in Iraq [6,7]. To date, no study has compared a pre-pandemic cohort with cohorts practising during and after the pandemic, via a multi-site design including nurse-level IPC competencies and health facility-level HAI rates. This study was undertaken to fill these gaps, with two goals: to capture the extent of changes to IPC practice in the pandemic era for Iraqi nurses and to identify remaining challenges that should be addressed by policymakers.

We hypothesised that nurses who worked during and following the COVID-19 pandemic would show significantly higher IPC knowledge scores, improved IPC practice adherence and reduced HAI rates when compared with a historical cohort. We also expected improvements in structural IPC readiness (PPE, isolation wards, ABHR) would be present and potentially mediate improvements in practice and outcomes. Through testing these hypotheses in eight hospitals in four governorates of Iraq, we sought to create knowledge that would be relevant and applicable to the Iraqi nursing and public health landscape.

MATERIALS AND METHODS

Study design and setting. A cross-sectional multi-site design was used. Eight tertiary hospitals in four governorates of Iraq were surveyed: Baghdad (Al-Kindy Teaching Hospital and Medical City Complex); Basra (Basra General Hospital and Al-Mawani Hospital); Salah al-Din (Tikrit Teaching Hospital and Samarra General Hospital); and Kirkuk (Kirkuk General Hospital and Azadi Teaching Hospital). These hospitals were chosen to represent different geographical locations, hospital sizes (150-620 beds) and both medical and surgical specialties.

Study cohorts. Given the cross-sectional design, temporal cohorts were identified retrospectively based on the period of practice during the last 18 months in which each nurse spent most of their time. Pre-COVID cohort: dominant practice from January 2017 to December 2019 (n=97). COVID-Era cohort: dominant practice between March 2020 and December 2021 (n=101). Post-COVID cohort: dominant practice between January 2022 and December 2023 (n=96). This approach allowed for the comparative assessment of cohort-specific IPC knowledge and practice, while recognising the limitations of the design to make causal statements over time.

Participants. We recruited registered nurses, aged 22-58 years with a minimum of 12 months of continuous clinical experience in medical, surgical or critical care. Participants with partial

completion of questionnaires (>10% items missing), on long-term leave during the study period and those with solely administrative positions for more than six months in the reference period were excluded. A total of 294 nurses (91.9% response rate) out of 320 invited completed the study protocol.

Instruments. Knowledge of IPC was measured by a 40-item valid tool based on the WHO IPC core components [17]. It assessed knowledge relating to transmission pathway knowledge, standard precautions, transmission-based precautions, environmental decontamination and sterilisation principles. An overall score (0-100) was obtained from a weighted average of items; coefficient alpha was 0.87 in this study. Adherence to practice was determined using a direct-observation checklist, administered by two trained research assistants during four unannounced 60-minute observations per nurse. This included adherence to hand hygiene, use of PPE, aseptic technique, isolation protocol, and environmental decontamination, based on WHO IPC core component standards [17]. Hospital-level HAI data were obtained from hospital surveillance reports for the respective periods for overall HAI rate, CLABSI, CAUTI, VAP, SSI, methicillin-resistant Staphylococcus aureus (MRSA) acquisition and Clostridioides difficile infection rates. Contextual factors and challenges were evaluated through a 30-question survey adapted from the WHO IPC assessment framework that included the regular availability of PPE, ABHR availability, number of isolation rooms, support of the IPC committee, and IPC fatigue.

Ethical considerations. The study was reviewed and approved by the University of Samarra Ethics Committee (Ref. USC-2023-087), and by the institutional review board of each hospital. Informed consent was sought and gained from each subject. Data were linked to codes to ensure anonymity and participation in the study was voluntary.

Statistical analysis

Descriptive statistics were calculated for each variable. One-way ANOVA with Tukey honest significant difference post-hoc tests were used to compare continuous outcomes of the three groups. Categorical variables were compared across the cohorts using Pearson's chi-squared or Fisher's exact test if cell counts were less than five. A p value of less than 0.05 was considered statistically significant. Data were analysed in IBM SPSS Statistics 28 (IBM Corp, Armonk, NY, USA).

RESULTS

The three cohorts were comparable in age and sex distribution (Table 1). Significant inter-cohort differences emerged across all IPC knowledge and training indicators. Formal IPC training receipt increased from 42.3% (Pre-COVID) to 88.1% (COVID-Era) and 94.8% (Post-COVID) ($p<0.001$), accompanied by increases in training hours from 6.2 ± 3.4 to 28.4 ± 7.3 ($p<0.001$). The IPC composite knowledge score demonstrated progressive, statistically significant improvement: 52.4 ± 9.8 (Pre-COVID), 71.6 ± 8.4 (COVID-Era), 81.3 ± 7.2 (Post-COVID), with all pair-wise Tukey comparisons significant at $p<0.001$. WHO Five Moments knowledge was correct in 91.7% of Post-COVID nurses versus 39.2% in the Pre-COVID cohort ($p<0.001$). Correct PPE donning and doffing knowledge showed comparable improvement (35.1% to 93.8%; $p<0.001$).

Table 1. Demographics of participants, details of IPC training and composite knowledge scores of the three nursing groups.

Characteristic	Pre-COVID (n=97)	COVID-Era (n=101)	Post-COVID (n=96)	p-value
Age, years (Mean ± SD)	32.4 ± 6.8	33.1 ± 7.2	33.8 ± 6.5	0.531
Female sex — n (%)	72 (74.2)	76 (75.2)	72 (75.0)	0.975
BSc in Nursing — n (%)	68 (70.1)	74 (73.3)	77 (80.2)	0.201
Clinical experience ≥5 years — n (%)	52 (53.6)	57 (56.4)	63 (65.6)*	0.043
Formal IPC training received — n (%)	41 (42.3)	89 (88.1)*	91 (94.8)*†	<0.001
IPC training hours (Mean ± SD)	6.2 ± 3.4	22.8 ± 6.1*	28.4 ± 7.3*†	<0.001
IPC composite knowledge score (0–100)	52.4 ± 9.8	71.6 ± 8.4*	81.3 ± 7.2*†	<0.001
WHO Five Moments knowledge — n (%)	38 (39.2)	78 (77.2)*	88 (91.7)*†	<0.001
Correct PPE donning/doffing knowledge — n (%)	34 (35.1)	82 (81.2)*	90 (93.8)*†	<0.001

Note. *ABHR = alcohol-based hand rub; IPC = infection prevention and control; PPE = personal protective equipment; WHO = World Health Organization. All values are Mean ± SD unless otherwise stated. * p<0.05 vs. Pre-COVID cohort; † p<0.05 vs. COVID-Era cohort (Tukey post-hoc test or chi-squared test as appropriate).*

Table 2. IPC practice adherence scores and compliance rates across the three nursing cohorts.

Practice Domain	Pre-COVID (n=97)	COVID-Era (n=101)	Post-COVID (n=96)	p-value
Overall IPC adherence score (0–100)	54.6 ± 10.2	74.8 ± 8.7*	83.7 ± 6.9*†	<0.001
Hand hygiene compliance (%)	61.4 ± 10.2	84.3 ± 7.6*	92.8 ± 5.7*†	<0.001
PPE consistent use — n (%)	37 (38.1)	86 (85.1)*	88 (91.7)*†	<0.001
Isolation protocol adherence (%)	58.2 ± 11.4	76.4 ± 9.2*	85.6 ± 7.8*†	<0.001
Aseptic technique adherence (%)	62.8 ± 9.7	77.3 ± 8.4*	86.2 ± 6.9*†	<0.001
Environmental decontamination adherence (%)	51.7 ± 12.1	71.8 ± 9.6*	81.4 ± 8.2*†	<0.001
Standard precautions score (0–10)	5.8 ± 1.6	7.9 ± 1.2*	8.7 ± 1.0*†	<0.001
Sharps disposal compliance — n (%)	66 (68.0)	89 (88.1)*	92 (95.8)*†	<0.001
IPC bundle adherence (≥80%) — n (%)	28 (28.9)	74 (73.3)*	82 (85.4)*†	<0.001

Note. *ABHR = alcohol-based hand rub; IPC = infection prevention and control; PPE = personal protective equipment. IPC bundle adherence ≥80% defined using the WHO IPC composite observation checklist. Adherence percentages and scores are Mean ± SD unless otherwise stated. * p<0.05 vs. Pre-COVID cohort; † p<0.05 vs. COVID-Era cohort.*

IPC practice adherence improved markedly and progressively across all observed domains (Table 2). Overall IPC adherence scores rose from 54.6 ± 10.2 (Pre-COVID) to 74.8 ± 8.7 (COVID-Era) to 83.7 ± 6.9 (Post-COVID) (p<0.001). Hand hygiene compliance

demonstrated the most pronounced improvement, increasing from 61.4 ± 10.2% to 92.8 ± 5.7% across the Pre-COVID to Post-COVID interval (p<0.001). Consistent PPE use rose from 38.1% to 91.7% (p<0.001). Isolation protocol adherence, aseptic technique compliance, environmental decontamination adherence, and standard precautions scores all followed parallel improvement trajectories with significant differences across all three cohort pair-wise comparisons. The proportion of nurses meeting the ≥80% IPC bundle adherence threshold increased from 28.9% (Pre-COVID) to 85.4% (Post-COVID) (p<0.001).

Table 3. Healthcare-associated infection rates by cohort reference period.

HAI Outcome	Pre-COVID (n=97)	COVID-Era (n=101)	Post-COVID (n=96)	p-value
Overall HAI rate (%)	14.8 ± 3.6	9.7 ± 2.8*	5.9 ± 1.9*†	<0.001
CLABSI (per 1,000 device-days)	4.8 ± 1.4	2.9 ± 1.0*	1.6 ± 0.7*†	<0.001
CAUTI (per 1,000 catheter-days)	5.2 ± 1.7	3.4 ± 1.2*	2.1 ± 0.9*†	<0.001
VAP (per 1,000 ventilator-days)	8.6 ± 2.3	5.4 ± 1.8*	3.2 ± 1.2*†	<0.001
SSI rate (%)	6.4 ± 2.1	4.2 ± 1.6*	2.6 ± 1.0*†	<0.001
MRSA acquisition rate (%)	3.8 ± 1.4	2.6 ± 1.1	1.4 ± 0.6*†	0.003
C. difficile (per 10,000 patient-days)	12.4 ± 3.8	8.7 ± 2.6*	5.1 ± 1.8*†	<0.001
HAI-attributable mortality (%)	4.2 ± 1.6	2.8 ± 1.2*	1.5 ± 0.7*†	0.001

Note. *CAUTI = catheter-associated urinary tract infection; CLABSI = central line-associated bloodstream infection; HAI = healthcare-associated infection; MRSA = methicillin-resistant Staphylococcus aureus; SSI = surgical site infection; VAP = ventilator-associated pneumonia. All values are Mean ± SD per respective denominators. * p<0.05 vs. Pre-COVID cohort; † p<0.05 vs. COVID-Era cohort.*

HAI outcomes demonstrated substantial and statistically significant improvement across the three cohort periods (Table 3). The overall HAI rate declined from 14.8 ± 3.6% (Pre-COVID) to 9.7 ± 2.8% (COVID-Era) and further to 5.9 ± 1.9% (Post-COVID) (p<0.001 for all cohort comparisons). CLABSI rates fell from 4.8 ± 1.4 per 1,000 device-days to 1.6 ± 0.7 (p<0.001), representing a 66.7% reduction. CAUTI rates declined from 5.2 ± 1.7 to 2.1 ± 0.9 per 1,000 catheter-days (p<0.001), and VAP from 8.6 ± 2.3 to 3.2 ± 1.2 per 1,000 ventilator-days (p<0.001). SSI rates declined from 6.4 ± 2.1% to 2.6 ± 1.0% (p<0.001). MRSA acquisition and C. difficile infection rates also declined significantly (p=0.003 and p<0.001, respectively). HAI-attributable mortality fell from 4.2 ± 1.6% to 1.5 ± 0.7% (p=0.001).

Structural and contextual IPC factors changed in tandem with the cohort progression (Table 4). Reliable PPE supply increased from 38.1% (Pre-COVID) to 91.7% (Post-COVID) (p<0.001). Access to point-of-care ABHR was reported by 89.6% of Post-COVID nurses compared to 42.3% of Pre-COVID nurses (p<0.001). Sufficient availability of isolation rooms increased from 29.9% to 71.9% (p<0.001) during this period. Perception of IPC committee support grew from 34.0% to 77.1% (p<0.001) and the proportion of surveillance data feedback to frontline nurses increased from 22.7% to 79.2% (p<0.001). IPC fatigue had a unique non-linear trend, with an increase in the COVID-Era cohort (56.4%) and a decrease in the Post-COVID cohort (32.3%) (p<0.001). Perception of staffing shortage as a barrier to IPC practice reduced from 63.9% (Pre-COVID) to 42.7% (Post-COVID) (p<0.001), but was still common.

Table 4. IPC challenges, structural facilitators, and infrastructure support across the three nursing cohorts.

Challenge / Facilitator	Pre-COVID n=97 (%)	COVID-Era n=101 (%)	Post-COVID n=96 (%)	p-value
PPE availability — consistent supply — n (%)	37 (38.1)	72 (71.3)*	88 (91.7)*†	<0.001
Adequate isolation room availability — n (%)	29 (29.9)	54 (53.5)*	69 (71.9)*†	<0.001
Functional ABHR dispensers at point-of-care — n (%)	41 (42.3)	79 (78.2)*	86 (89.6)*†	<0.001
IPC committee support perceived — n (%)	33 (34.0)	64 (63.4)*	74 (77.1)*†	<0.001
IPC fatigue/burnout reported — n (%)	18 (18.6)	57 (56.4)*	31 (32.3)*†	<0.001
Staffing shortage as IPC barrier — n (%)	62 (63.9)	74 (73.3)	41 (42.7)*†	<0.001
IPC policy clarity score (0–10)	4.8 ± 1.9	7.1 ± 1.4*	8.2 ± 1.1*†	<0.001
Surveillance feedback to frontline nurses — n (%)	22 (22.7)	61 (60.4)*	76 (79.2)*†	<0.001

Note. *ABHR = alcohol-based hand rub; IPC = infection prevention and control; PPE = personal protective equipment. IPC fatigue defined as self-reported exhaustion specifically attributed to sustained IPC practice demands. All values are n (%) unless otherwise stated. * p<0.05 vs. Pre-COVID cohort; † p<0.05 vs. COVID-Era cohort.*

DISCUSSION

Our study provides the most extensive multi-site evidence to date of the changes in IPC knowledge, practice and patient outcomes in Iraqi nursing from the pre-pandemic, during-pandemic, and post-pandemic eras. Our key finding that composite IPC knowledge, practice and HAI outcomes improved and were significantly different across the three cohorts, supports the hypothesis that the COVID-19 pandemic provided an unintentional but significant catalyst for the long-term capacity building of IPC in Iraqi hospitals.

The absolute increase in composite IPC knowledge scores from 52.4 (Pre-COVID) to 81.3 (Post-COVID) is clinically relevant, and aligns with evidence from similar health systems. Similar improvement in nurse IPC knowledge scores has been reported from Iran and Jordan, with improvements generally ascribed to intensive emergency training, dissemination of WHO IPC guidelines, and increased institutional attention to IPC [18,19]. The parallel rise in the proportion of respondents who reported receiving formal IPC training (from 42.3% to 94.8%) suggests that the exposure of nurses to this training, rather than its quality, was a key factor of improvement in knowledge scores - a finding that echoes that of systematic reviews of IPC capacity building in low-middle income countries [20].

Hand hygiene compliance is considered the most effective and cost-benefit efficient IPC measure [17]. That our study found an increase in compliance from 61.4% to 92.8% between the Pre-COVID and Post-COVID groups is particularly notable. Our pre-pandemic rates are in line with previous studies in Iraq and other settings with limited resources [6,21]. The marked improvement in the post-pandemic cohort is likely attributable to a combination of factors: greater nurse understanding of the spread of infection, more readily accessible ABHR at point-of-care, and increased awareness of the importance of hand hygiene for patient protection and for personal protection in the midst of a pandemic caused by a respiratory pathogen [22]. Crucially, our data show this improvement sustained and improved in the Post-COVID cohort compared to the COVID-Era cohort, making it clear that this was not a "spike" in compliance driven by fear of SARS-CoV-2 infection alone.

The corresponding reductions in device-associated HAIs (CLABSI, CAUTI and VAP), and in SSI, MRSA and C. difficile rates are significant. Similar reductions have been reported in European hospitals during the COVID era [11,23], and attributed to the "bundle adherence halo effect" - the propensity for the extra vigilance around IPC during the pandemic to encourage more consistent adherence to device care bundles and surgical preparation bundles. Our findings indicate this was the case in Iraqi hospitals, and, significantly, that it continued beyond the pandemic. Prospective longitudinal studies are needed to determine whether this is due to sustained habit formation, or institutional infrastructure (including IPC surveillance and accountability) or ongoing IPC engagement.

The finding of IPC fatigue is telling from an industrial relations perspective. The prevalence of self-reported IPC fatigue was highest in the COVID-Era cohort (56.4%), significantly higher than the Pre-COVID (18.6%) and Post-COVID (32.3%) cohorts. This U-curve probably reflects the temporary psychological and physical demands of responding to unprecedented IPC challenges underperio The decrease in fatigue in the Post-COVID cohort - despite this cohort reporting higher fatigue than the Pre-COVID cohort - may be related to improved staffing ratios, normalised PPE protocols, and a decrease in existential threat. The fact that 33% of Post-COVID nurses still report IPC fatigue suggests fatigue and occupational wellbeing must remain integral to an ongoing IPC strategy [25].

Infrastructure change was marked, and likely to have contributed a mechanistic role in changing practice. The virtually universal availability of PPE and point-of-care access to ABHR reported by Post-COVID nurses stands in stark contrast to pre-pandemic reports here and other Iraqi studies. Although the number of isolation rooms remains suboptimal, more than doubling over the study period. These improvements are likely a result of emergency capital funding during the pandemic, international donor assistance, and policy changes inspired by the WHO IPC assessment framework, adopted by the Iraqi Ministry of Health in 2021. To maintain these gains - as emergency funding and political will are diverted to other issues - it will take concerted policy efforts and sustained budget allocation for infrastructure investment.

These results have limitations to be considered. The cross-sectional study design does not allow causal inference, and retrospective cohort allocation may have led to misclassification bias for nurses with practice in more than one defined period. HAI data were abstracted from hospital records, which may differ in sensitivity of surveillance systems between facilities and over time. Self-reported practice items may have been subject to social desirability bias, although this was addressed by the direct-observation component in the adherence assessment. The findings may not be applicable to rural Iraqi hospitals or district-level facilities, as all sites were urban tertiary-care hospitals. Finally, the study did not measure the specific IPC measures available in each facility during each period to support mechanistic analyses.

Despite these limitations, the multi-site nature of the study, inclusion of nurse and facility-level outcome measures, and comparison of three cohort periods are major strengths. The results offer localised evidence for policymakers, educators and leaders in Iraqi and other post-war, low-resourced settings to sustain IPC improvements during the pandemic.

CONCLUSION

The COVID-19 pandemic, despite the devastating impacts on Iraq's healthcare system, triggered and sustained gains in nurse IPC knowledge, adherence, and patient outcomes from HAI at the study institutions. Increasing adherence to hand hygiene, use of personal protective equipment (PPE), adherence to device care bundles and the establishment of IPC infrastructure were associated with remarkable reductions in catheter-associated bloodstream infections (CLABSI), catheter-associated urinary tract infections (CAUTI), ventilator-associated pneumonia (VAP), surgical site infections (SSI), and overall HAI. These results suggest a

proactive approach to locking in pandemic IPC gains, rooted in ongoing training support, the establishment of IPC committees, regular infrastructure funding and initiatives to counter the remaining IPC fatigue among front-line nurses. Longitudinal studies and inclusion of rural and district hospitals in future research will help paint a broader picture of national post-pandemic IPC capacities in Iraq.

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