RESEARCH BRIEFS

Patterns of Nosocomial Infections, Multidrug-Resistant Microorganisms, and Mold Detection after Extensive Black-Water Flooding: A Survey from Central Thailand

Central Thailand was severely affected by black-water flooding between September and November 2011, with resultant closure of 30 regional hospitals. Few data are available for the incidence of nosocomial infections and patterns of preflood versus postflood multidrug-resistant organisms (MDROs) and mold. We therefore conducted a survey of the hospitals in central Thailand in order to evaluate the patterns of nosocomial infections, MDROs, mold, and flood preparedness plans after these floods.

On the basis of a hospital list from the Ministry of Public Health, we identified 104 hospitals in 15 provinces of central Thailand that were affected, but not necessarily closed, by extensive floods. We designed and then conducted a survey, from July 1 through October 31, 2012, that inquired about hospital characteristics, postflood hospital preparedness plans, administrative support, institutional safety culture,[1,2] incidence of nosocomial infections, and prevalence of MDROs and mold colonization or infection. All 104 secondary care (>100 beds) and tertiary care (>250 beds) hos-

TABLE 1. Characteristics and Flood Preparedness Plan of 101 Hospitals from Central Thailand

Variables	Hospitals (N = 101)[a]
Hospital characteristics	
Type of hospital	
Secondary care	36 (36)
Tertiary care	65 (64)
Medical school affiliation	40 (40)
Infectious diseases specialist	55 (55)
Hospital epidemiologist	46 (46)
Infection control and/or occupational health department	89 (88)
Hospital engineer	28 (28)
Microbiology laboratory	77 (76)
No. of beds, median (range)	500 (100–2,000)
Safety score, median (range)[b]	7 (2–10)
Damaged by flood	32 (32)
Cost of postflood hospital renovations, median (range), million $US[c] ($N$ = 32)	6.3 (0.7–16.6)
Current hospital preparedness plans for flooding	
Had existing flood protocol	95 (94)
Ever conducted an exercise or drill for the flood protocol (N = 95)	63 (66)
Had protocol to help hospital personnel and families during and after flood	86 (85)
Adequate stockpile of PPE for use during and after flood	96 (95)
Had protocol for appropriate PPE use	80 (79)
Had surge capacity plans during and after flood	86 (85)
Had plans for opening flood-unaffected units for use during and after flood	90 (89)
Had environmental cleaning and mold decontamination protocols during and after flood	42 (41)
Had plans for operating isolation units during and after flood	59 (58)
Had plans for operating clinical laboratories during and after flood	46 (45)
Had protocol for equipment disinfection and sterilization	44 (43)
Had protocol for waste management	71 (70)

NOTE. Data are number (%) of hospitals, unless otherwise indicated. Three 3-hour training sessions were conducted (by A.A.) to instruct the 5 research nurses on the survey tool and data collection processes. The survey instrument was pilot tested in 10 hospitals to ensure test validity among the 5 research nurses. All 5 research nurses individually interviewed the same person at 10 hospitals, and reliability checks were performed; 100% concordance in data capture was achieved. The research nurses then conducted 1-hour interviews of each participating hospital's lead infection preventionist. PPE, personal protection equipment.

[a] N = 101, unless otherwise indicated.

[b] The institutional safety culture was measured by a 2-matrix safety score, calculated as the average of responses for agreement with 2 statements: "Leadership is driving us to be a safety-centered institution" and "I would feel safe being treated here as a patient."

[c] $1 US = 30 baht.

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TABLE 2. Factors Associated with Postflood Change in Incidence or Prevalence of Multidrug-Resistant (MDR) Microorganisms and Mold Infection and/or Colonization

Infection/colonization	Change in incidence/prevalence	Factors	Adjusted odds ratio (95% CI)	*P*
Mold[a]	Increased	Lack of environmental cleaning and mold decontamination protocols during and after flood	58.3 (14.19–87.10)	<.001
		Lack of surge capacity plans during and after flood	26.5 (2.38–97.3)	.008
		Noncompliance with infection control measures	16.67 (1.28–77.60)	.02
MDR *Acinetobacter baumannii*	Decreased	Safety score[b]	1.71 (1.01–2.91)	.01
MDR *Pseudomonas aeruginosa* infection	Decreased	Safety score[b]	1.96 (1.21–3.69)	.03
ESBL-producing Enterobacteriaceae	Decreased	Safety score[b]	1.61 (1.04–2.71)	.04
Methicillin-resistant *Staphylococcus aureus*	Decreased	Safety score[b]	1.11 (0.98–2.82)	.08

NOTE. ESBL, extended spectrum β-lactamases; MDR, multidrug resistant.

[a] Hospitals may have reported more than one type of mold detection, with a distribution of *Aspergillus* spp (19/25 [76%]), *Fusarium* spp (12/25 [48%]), *Penicillim* spp (10/25 [40%]), *Paecilomyces* spp (2/25 [8%]), and *Philophora* spp (1/25 [4%]).

[b] Institutional safety culture was measured by a 2-matrix safety score, calculated as the average of responses for agreement with 2 statements: "Leadership is driving us to be a safety-centered institution" and "I would feel safe being treated here as a patient." To determine factors associated with outcomes of interest, variables that were present at a significance level of $P < .20$ in univariate analysis were entered into multivariate logistic regression models. Adjusted odd ratios and 95% confidence intervals (CI) were calculated.

pitals in 15 central Thailand provinces were invited to participate. Nosocomial infections included central line–associated bloodstream infection (CLABSI), ventilator-associated pneumonia (VAP), hospital-acquired pneumonia (HAP), and catheter-associated urinary tract infection (CAUTI); the MDRO list included MDR *Pseudomonas aeruginosa*, MDR *Acinetobacter baumannii*, extended-spectrum β-lactamase (ESBL)–producing Enterobacteriaceae, methicillin-resistant *Staphylococcus aureus* (MRSA), and mold colonization or infection. Median incidence of nosocomial infections and prevalence of MDROs and molds in the flooded ($n = 32$) and nonflooded ($n = 69$) hospitals during the initial 6-month period after the flood (postflood) were compared with similar measures for the same 6-month period 1 year prior to the flood (preflood).

Data on nosocomial infections were derived from hospital surveillance for CLABSI, VAP, HAP, and CAUTI. Data on MDROs, mold type, and the distinction between mold colonization and infection were derived from laboratory surveillance, together with hospital-specific infection control surveillance data. Duration of nosocomial infections and MDROs of interest were monitored for months 1–6 of the postflood interval and compared to the incident estimates during the same 6-month preflood period. Nosocomial infections were defined according to Centers for Disease Control and Prevention definitions.[3] The criterion for pathogen-specific MDR categorization was resistance to at least 1 drug in more than 3 classes of antibiotics.[4] This study was approved by the Institutional Review Board of Faculty of Medicine, Thammasat University.

A total of 101 of the 104 eligible hospitals (97.1%) responded to the survey; 69 (68%) were not flooded and 32 (31%) were damaged by the flood, of which 30 required closure. Hospital characteristics and details of hospital preparedness plans 6 months after the floods are summarized in Table 1. During the postflood interval, the incidences of the defined nosocomial infections remained unchanged from their preflood levels: (1) CLABSI, from 3.4 to 3.6 per 1,000 catheter-days ($P = .91$); (2) VAP, from 3.1 to 2.4 per 1,000 ventilator-days ($P = .83$); (3) HAP, from 3 to 2.1 per 1,000 patient-days ($P = .79$); and (4) CAUTI, from 4 to 3.8 per 1,000 catheter-days ($P = .89$). Significant reduction in MDROs was observed only for MDR *A. baumannii* (from 6.5 to 1.8 per 1,000 patient-days; $P < .001$), while there was a trend toward reduction in MDR *P. aeruginosa* (from 2.5 to 1.8 per 1,000 patient-days; $P = .23$), ESBL-producing Enterobacteriaceae (from 3.6 to 2.4 per 1,000 patient-days; $P = .12$), and MRSA (from 2.5 to 1.5 per 1,000 patient-days; $P = .11$). There were no differences in nosocomial infection rates, MDROs, or mold detection between the pre- and postflood periods among the 69 nonflooded hospitals. Overall, the interviewee at 25 of 32 hospitals (76%) reported an increase in the prevalence of mold infection or colonization (19/25 [76%] with colonization vs 6/25 [24%] with mixed colonization and infection). Although not statistically significant, the prevalence of colonization or infection increased

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by 44% (from 0.5 to 0.9 per 1,000 patient-days; $P = .29$). Multivariate analysis of factors associated with postflood change in estimates of MDR microorganisms and mold is summarized in Table 2.

In this study, the institutional safety culture was the only factor associated with reduction in detection of many MDROs after the extensive black-water floods. It is plausible to hypothesize that the institutional safety culture is a proxy measure for the benefits of leadership associated with promotion of best infection prevention control practices, inclusive of thorough environmental cleaning after the extensive floods.[5] In a prior single-center study, the authors suggested that termination of an MDR *A. baumannii* outbreak was achieved after thorough environmental cleaning after flooding.[6] Given the high prevalence of MDR *A. baumannii* in Thailand during the preflood period, a statistically significant reduction in the identification of this pathogen during the postflood period likely was associated with the ongoing strategic infection prevention control strategy of environmental cleaning.[7] In addition, the 44% increase in mold detection at the flooded hospitals, compared to the lack of change in mold detection at the nonflooded hospitals, suggests that there is need for postflood mold surveillance, together with a need to measured compliance with mold decontamination protocols and experiential practices related to such protocols.[8,9]

There are some recognized limitations to this study. First, the study was conducted to report the epidemiology of nosocomial infections, MDROs, and mold detection in the initial 6-month postflood interval, and the results may not reflect the long-term impact of flooding. Second, we relied on self-reported data, and it is plausible that the survey respondents over- or underestimated the frequency of the real practices related to hospital preparedness plans. Third, it is plausible that the increase in the prevalence of mold colonization and infection reflected an increase in the community-acquired infections rate in the flood regions. Finally, the small sample size did not permit us to identify other factors associated with the change in patterns of nosocomial infections, MDROs, or mold detection.

In conclusion, this is the first study to report patterns of nosocomial infections, MDROs, and mold detection after extensive black-water floods. Our findings highlight the benefits associated with postflood environmental cleaning and a mold decontamination protocol and a strong institutional safety culture. Improvements in hospitals' safety culture, together with these infection control measures, may help hospitals reduce incident infections associated with MDROs and mold after extensive black-water floods.

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