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ORIGINAL ARTICLE

The Type, Level, and Distribution of Microorganisms within the Ward Environment: A Zonal Analysis of an Intensive Care Unit and a Gastrointestinal Surgical Ward

Ginny Moore, PhD;¹ Monika Muzslay, MSc;¹ A. Peter R. Wilson, MD, FRCP, FRCPath¹

OBJECTIVE. To investigate the distribution of hospital pathogens within general and critical care ward environments and to determine the most significant bacterial reservoirs within each ward type.

DESIGN. Prospective 4-month microbiological survey.

SETTING. The intensive care unit (ICU) and gastrointestinal (GI) surgical ward of a London teaching hospital.

PATIENTS. Sampling was conducted in and around the bed space of 166 different patients (99 in the ICU and 67 in the GI ward).

METHODS. Conventional agar contact methodology was used to sample 123 predetermined sites twice a week for 17 weeks. Sixty-one surfaces were located within the ICU, and 62 were located within the GI ward. Each surface was located within a theoretical zone of increasing distance from the patient. Aerobic colony counts were determined, and confirmatory testing was conducted on all presumptive pathogens.

RESULTS. Regardless of ward type, surfaces located closest to the patient, specifically those associated with the bed (side rails, bed control, and call button), were the most heavily contaminated. Elsewhere, the type of surfaces contaminated differed with ward type. In the ICU, bacteria were most likely to be on surfaces that were regularly touched by healthcare workers (eg, telephones and computer keyboards). **In the GI ward, where the patients were mobile, the highest numbers of bacteria (including potential nosocomial pathogens) were on surfaces that were mainly touched by patients, particularly their toilet and shower facilities.**

CONCLUSIONS. In terms of cleaning, a hospital should not be considered a single entity. Different ward types should be treated as separate environments, and cleaning protocols should be adjusted accordingly.

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Patients associate a clean, well-cared-for environment with the quality of their care and their safety.¹ Their perception of cleanliness depends as much on the standard of the décor and storage of equipment as it does on the removal of biological soil and dust. However, although the appearance of the environment in terms of maintenance, housekeeping, and design can be assessed visually, the cleanliness of the environment cannot. Visual assessment is a poor indicator of cleaning efficacy,^{2,3} and although some hospitals have used adenosine triphosphate bioluminescence^{4,5} or a fluorescent marker⁶ to assess the effectiveness of cleaning protocols, the cleaning programs themselves are usually not evidence based.⁷

Emphasis is traditionally placed on the frequent and thorough cleaning of those sites with which staff and patients have frequent contact. However, evidence to support such cleaning programs is generally weak. Little consideration is given to the work and movement patterns of staff and patients

or how ward types may differ in terms of the type of bacteria present and the type of surface contaminated. The aims of this investigation were to investigate the distribution of hospital pathogens in both general and critical care ward environments and to establish the bacterial reservoirs associated with each type of ward.

METHODS

Study Setting

This prospective study was undertaken at a London teaching hospital between August 24 and December 16, 2009. Two different wards were included in the study: the general medical-surgical intensive care unit (ICU) and the gastrointestinal (GI) surgical ward.

The ICU comprised 11 single rooms (all at negative pressure), 4 bays of 5 beds, and 1 bay of 4 beds. The GI ward

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comprised 7 single rooms (all at neutral pressure) and 14 bays of 4 beds. All bays were single sex. The domestic staff performed daily routine cleaning between 0730 and 1600 hours. Surfaces (unoccupied beds, doors, sinks, and bins) were cleaned using damp microfiber cloths (Jonmaster). The nonoutbreak cleaning protocol did not incorporate a surface disinfectant. In the ICU, the nurses used a chlorine dioxide-based gel (Tristel Solutions) for damp dusting. They were expected to clean the bed area and associated equipment once per shift.

All patients were screened for methicillin-resistant *Staphylococcus aureus* (MRSA) at hospital admission and weekly during their stay. Other pathogens were not routinely screened but were recognized through clinical samples. Liaison with infection control and laboratory staff enabled daily prospective surveillance of all known colonizations and infections. Bed occupancy was recorded on a daily basis, and ward maps were produced that detailed the location of each patient.

Sample Sites

Microbiological sampling was conducted within 1 bay and 1 isolation room within each ward. Sixty-one predetermined surfaces were sampled within the ICU, including 41 within the test bay and 20 within the isolation room. Sixty-two surfaces were sampled within the GI ward, including 45 within the test bay and 17 within the isolation room (Table 1). Each surface was located within a theoretical zone of increasing distance from the patient. Similar zoning assessments have been used within the food industry, particularly in the control of *Listeria monocytogenes* in foodstuffs.⁸

Microbiological Analysis

Conventional agar contact methodology was used to detect the presence of bacteria on the environmental surfaces. Direct contact methods have greater sampling efficiency and are more reproducible than swabbing.^{9,10} Blood agar contact plates (diameter, 55 mm; Oxoid) were used to determine the aerobic colony count. Double-sided dipslides (11 cm² × 2; Dimanco) incorporating mannitol salt agar and kanamycin esculin azide agar were used to aid the identification of *S. aureus* and *Enterococcus* species.

Each surface was sampled 33 times over the 17-week study period. To minimize the error associated with being unable to standardize the level of bioburden present, the 3 agar plates were pressed (using similar force) onto 3 adjacent surface areas. All plates were incubated at 37°C for 48 hours. Confirmatory tests were conducted on all presumptive pathogens.

Statistical Analysis

Median aerobic colony counts were calculated. Intergroup comparisons were made with the Mann-Whitney *U* test conducted using IBM SPSS Statistics, version 20.

RESULTS

Intensive Care Unit

Five-bed bay. Zone 1, which was the zone closest to the patient, was the most heavily contaminated area of the ICU bay (Table 2). The lowest aerobic colony counts were recovered from surfaces within zone 2, which was the near-patient environment. Comparatively higher numbers of bacteria were recovered further from the patient, particularly from paper towel dispensers, bin lids, and sinks located within the wider bed space (zone 3) and from telephones and computer keyboards located within the wider bay environment (zone 4).

Sampling was conducted in and around the bed space of 84 different patients, 2 of whom were colonized with MRSA. MRSA was recovered from 6 surfaces located in the ICU bay, but none were within the bed space of a patient who was positive for MRSA. MRSA was more likely to be recovered from the wider ICU environment in zone 6 (staff toilet area) and zone 7 (clinical information station; Table 3). Of the 13 patients admitted with a gram-negative infection, 7 were infected with *Escherichia coli*. However, *E. coli* was not detected on any of the surfaces sampled. Conversely, there were no known colonizations or infections due to *Acinetobacter baumannii*, yet this organism was frequently recovered from surfaces within the near-patient environment (zone 2). The majority of gram-negative organisms were recovered from zones 3 and 6, where the presence of moisture likely enhanced microbial survival (Table 3). Enterococci and methicillin-susceptible *S. aureus* (MSSA) were recovered throughout the ICU. However, although it was most likely to be contaminated with MSSA, zone 7 (the clinical information station) was the least likely to be contaminated with fecal flora (Table 3).

Isolation room. Sampling was conducted in and around the bed space of 15 different isolated patients. Four patients were colonized or infected with MRSA. As in the bay, high numbers of bacteria were recovered from the zone closest to the patient (zone 1). This zone was also the most likely to be contaminated with MRSA, enterococci, and gram-negative bacteria (Table 3). Comparatively few bacteria were recovered from within the near-patient environment (zone 2; Table 2), but MRSA and enterococci were recovered from the majority of sample sites on at least one occasion. However, MRSA was not always recovered from the environment of a patient positive for MRSA, and although one of the isolated patients was known to be positive for vancomycin-resistant enterococci, no site was contaminated with vancomycin-resistant enterococci.

Two patients were isolated with or because of a gram-negative urine infection; neither organism (*E. coli* and gentamicin-resistant *Pseudomonas aeruginosa*) was recovered from the environment. One patient was infected with *Klebsiella pneumoniae* (detected in a sputum sample), and the organism was isolated from a site within zone 2 (chair arm). As in the bay, despite there being no known colonization or

TABLE 1. Surfaces Associated with Sample Zones

Zone	ICU		GI ward	
	5-bed bay	Single isolation room	4-bed bay	Single isolation room
1	Patient bed: bed rail	Patient bed: bed rail	Near-patient environment (patient contact): nurse call button, bed control, over-bed table, patient chair (arm)	Patient bed: bed rail, nurse call button, over-bed table
2	Near-patient environment: bed control, syringe drive, equipment trolley, ventilator, chair arm, computer keyboard, privacy curtain	Near-patient environment: bed control, syringe drive, equipment trolley, ventilator, chair arm, computer keyboard, computer mouse, stethoscope, work surface, telephone	Near-patient environment (staff contact): bed footboard, patient record folder, drug locker, privacy curtain	Near-patient environment: bed footboard, chair arm, patient locker
3	Wider bed space: towel dispenser, apron dispenser, sink, bin lid	Wider room environment: towel dispenser, apron dispenser, bin lid, inner door handle	Patient toilet: shower head, shower seat handle, toilet assist bar, flush, inner door handle, outer door handle	Wider room environment: towel dispenser, sink, telephone, inner door handle
4	Wider bay environment: treatment trolley, work surface, telephone, computer keyboard, inner door panel, outer door panel	Outside single room: work surface, telephone, computer keyboard, computer printer, drug refrigerator	Wider bay environment: towel dispenser, bin, sink	En suite toilet: shower head, shower seat handle, toilet assist bar, flush, tap handle
5	Wider ward environment: blood gas analyzer, pneumatic tube system	N/A	Wider ward environment: medical notes trolley, blood pressure cuff, computer keyboard, computer mouse, work surface, staff chair arm, telephone, item of stationery, pneumatic tube system	Outside single room: outer door handle, patient record folder
6	Staff toilet: flush, tap handle, inner door handle, outer door handle	N/A	Staff toilet: flush, tap handle, inner door handle, outer door handle	N/A
7	Clinical information station: telephone, work surface, computer (clerk), computer (staff), item of stationery	N/A	N/A	N/A

NOTE. GI, gastrointestinal; ICU, intensive care unit; N/A, not applicable.

infection due to *A. baumannii*, this organism was frequently recovered from within zone 1 and zone 2. Gram-negative rods were most likely to be recovered from surfaces within zone 3 (the wider room environment, including bin lid, towel dispenser, and sink; Table 3).

Gastrointestinal Ward

Four-bed bay. In total, 1,473 samples were taken from within the GI bay. The median number of colonies recovered was 35 colony-forming units (cfu) per 25 cm², which was significantly higher ($P < .05$) than the median number of

colonies recovered from the ICU bay (20 cfu per 25 cm²; $n = 1,331$). Sampling was conducted in and around the bed space of 64 different patients. Three patients were colonized with MRSA, 2 with MSSA (detected in wound samples), and 5 had a gram-negative infection. Unlike the ICU, the patients admitted to the GI ward readily moved around their bed space. For the purposes of zonal analysis, therefore, surfaces within the near-patient environment were divided into 2 groups: primarily patient contact and primarily staff contact (Table 1).

Within the near-patient environment, significantly more

TABLE 2. Number and Distribution of Bacterial Contaminants within an Intensive Care Unit (ICU) and Gastrointestinal (GI) Ward

Zone	Aerobic colony count, median cfu per 25 cm ² (IQR)			
	ICU		GI ward	
	5-bed bay	Single isolation room	4-bed bay	Single isolation room
1	44 (19–107) (<i>n</i> = 33)	54 (20–124) (<i>n</i> = 33)	54 (28–83) (<i>n</i> = 132)	60 (22–113) (<i>n</i> = 93)
2	11 (6–24) (<i>n</i> = 231)	13 (4–30) (<i>n</i> = 324)	24 (13–45) (<i>n</i> = 132)	16 (4–35) (<i>n</i> = 97)
3	36 (17–62) (<i>n</i> = 132)	24 (14–59) (<i>n</i> = 132)	80 (40–157) (<i>n</i> = 196)	14 (8–30) (<i>n</i> = 132)
4	21 (10–39) (<i>n</i> = 198)	19 (9–50) (<i>n</i> = 165)	60 (28–134) (<i>n</i> = 99)	29 (12–67) (<i>n</i> = 165)
5	15 (11–31) (<i>n</i> = 66)	...	33 (16–55) (<i>n</i> = 292)	24 (14–54) (<i>n</i> = 66)
6	33 (17–67) (<i>n</i> = 124)	...	43 (20–79) (<i>n</i> = 128)	...
7	43 (21–90) (<i>n</i> = 164)

NOTE. See Table 1 for zone details. cfu, colony-forming units; IQR, interquartile range.

bacteria were recovered from patient contact sites (zone 1) than from staff contact sites (zone 2; Table 2). Patient contact sites were also more likely to be contaminated with MSSA (Table 4). MRSA was recovered from 15 surfaces, 2 of which were within the near-patient environment of an MRSA-positive patient (bed control [zone 1] and bed footboard [zone 2]). None of the gram-negative infective organisms (*E. coli*, *K. pneumoniae*, and *P. aeruginosa*) were recovered from within the respective bed space. **Of all the surfaces sampled, those associated with the patient toilet and shower facilities (zone 3) were the most heavily contaminated.** In comparison, the staff toilet area (zone 6) was significantly less contaminated ($P < .01$) and was less likely to be contaminated with staphylococci, enterococci, and gram-negative rods (Table 4).

As in the ICU, the widest variety of enteric and nonenteric gram-negative rods was recovered from bin lids, sinks, and towel dispensers (zone 4). Aerobic colony counts of greater than 100 cfu per 25 cm² were regularly recovered from bin lids (10 of 33 sampling occasions) and sinks (18 of 33) located within this zone (wider bay area). Although high levels of contamination were less common in the wider ward environment (zone 5), all sample sites were contaminated at levels greater than 100 cfu per 25 cm² on at least 1 sampling occasion. Most likely to be contaminated at such levels were items of stationary (6 of 33 sampling occasions), chair arms (6 of 33), blood pressure cuffs (5 of 32), and computer keyboards (8 of 66).

Isolation room. Sampling was conducted in and around the bed space of 3 different isolated patients. All had a gram-negative infection (gentamicin-resistant *Proteus mirabilis* and/or *E. coli*). Zone 1 was associated with the highest aerobic colony counts and was also the most likely to be contaminated with the infective organism. **Unlike the bay area, where the toilet and shower facilities were a hub of patient activity, the en suite toilet and shower (zone 4) were used infrequently. Significantly fewer bacteria were recovered from the en suite toilet and shower than from similar surfaces within the bay. Nonetheless, 14% (24 of 165) of the surfaces sampled were contaminated at levels greater than 100 cfu per 25 cm², and 28% were contaminated with enterococci (Table 4).** In total,

128 (23%) of the surfaces sampled in and around the isolation room were contaminated with enterococci; 48 of these were contaminated with a vancomycin-resistant strain.

DISCUSSION

The UK Department of Health has put hospital cleanliness at the center of its initiatives aimed at reducing the incidence of healthcare-associated infection. Cleaning has 2 main functions; to improve or restore appearance and to reduce both microorganisms and any substance that supports their growth to a level that minimizes patients' risk of acquiring an infection.¹¹ **However, for cleaning to be effective, it should be targeted to those areas that are most likely to be contaminated.**

We adopted a zoning strategy similar to that used by the food industry to successfully control *L. monocytogenes*. Effective *Listeria* control programs use an approach whereby a processing plant is divided into zones that reflect how near a surface or area is to the product. Sampling by zone helps management find potential sources of *Listeria* and focus control efforts on vulnerable areas.⁸ In our study, general and critical care wards, bays, and isolation rooms were divided into zones of increasing distance from the patient. Environmental sampling identified the most contaminated zones and those that posed the greatest risk in terms of cross-transmission.

In the ICU, the highest aerobic colony counts were in samples that were recovered from the zone closest to the patient (ie, the bed rail; zone 1; Table 2). The bed rail is one of the few surfaces in the ward environment that is touched by patients, staff, and visitors. As a result, bed rails can become heavily contaminated and can potentially form a significant reservoir of pathogenic bacteria near the patient.^{12,13} Sampling was conducted in and around the bed space of 15 different isolated patients, 4 of whom were colonized or infected with MRSA. Of the 33 bed rails that were sampled, 18% were contaminated with MRSA (Table 3). All contaminated rails were associated with beds occupied by MRSA-positive patients. Admission to a bed space previously occupied by a patient positive for MRSA significantly increases

TABLE 3. Distribution of Potential Pathogens within an Intensive Care Unit

Sample zone	Surfaces from which target organisms were recovered, %				
	MSSA	MRSA	VSE	VRE	Gram-negative rods ^a
5-bed bay					
Patient bed (zone 1; n = 65)	3	0	6	0	6
Near-patient environment (zone 2; n = 420)	4.5	0.7	6	0	7
Wider bed space (zone 3; n = 294)	4	0.7	6	0.3	21
Wider bay environment (zone 4; n = 198)	5.5	0.5	5	0	6
Wider ward environment (zone 5; n = 66)	4.5	0	3	1.5	4.5
Staff toilet (zone 6; n = 124)	6.5	3	5	0	16
Clinical information station (zone 7; n = 164)	11	2	0.6	0	3
Single isolation room					
Patient bed (zone 1; n = 33)	3	18	21	0	15
Near-patient environment (zone 2; n = 324)	4	7	9	0	5
Wider room environment (zone 3; n = 132)	2	5	3	0	18
Outside single room (zone 4; n = 165)	4	0.6	2	0	1

NOTE. MRSA, methicillin-resistant *Staphylococcus aureus*; MSSA, methicillin-susceptible *S. aureus*; VRE, vancomycin-resistant enterococci; VSE, vancomycin-susceptible enterococci.

^a Including *Acinetobacter baumannii*.

the odds of MRSA acquisition.¹⁴ If inadequately decontaminated, the bed rail can pose a risk of infection to patients.

Surface material and rugosity can affect how easy it is to clean bed rails. The rails associated with the ICU beds were textured. However, to facilitate the removal of microorganisms, bed rails should have low surface roughness, be free of microscopic irregularities, and be resistant to impact and abrasion damage.¹⁵ These findings have since been released to the bed manufacturers and have informed the tendering process for a contract for new beds in the hospital. Nonetheless, regardless of how easy a bed rail is to clean, the risk posed by a contaminated bed rail will depend upon the efficacy of the cleaning procedures employed.¹⁵ Regular wiping with antibacterial wipes has been recommended as a cost-effective means of maintaining low numbers of bacteria near to the patient.¹⁵

Within the ICU, the cleaning of the bed and all equipment and furniture near the patient is the responsibility of the bedside nurse on each shift and/or at patient discharge from the ICU. Nurses are unsupervised and may not see cleaning as part of their core responsibilities. Infrequent and/or inadequate cleaning of the environment near the patient may be one reason for the continuing high prevalence of nosocomial infections in many ICUs. In an earlier study, intensive cleaning of the near-patient environment was performed in addition to the cleaning routinely performed by the nursing staff. This enhanced cleaning regimen reduced the bacterial load on high-contact sites but was not associated with reduced colonization or infection of patients.¹⁶ During the current ward survey, surfaces within the near-patient environment (zone 2) were the least contaminated surfaces within the bay and single room (Table 2). This implies that the routine cleaning performed by the nursing staff was effective and to a high standard, and it indicates that, in our earlier study, the bac-

terial load near the patient and the potential risk to which the patients were exposed was already likely to have been low. This may have been the reason why the enhanced cleaning regimen did not prove cost-effective or clinically effective.¹⁶

The zonal analysis conducted as part of our study suggests that, in the ICU, additional and/or more frequent cleaning is required in zones located further from the patient. Comparatively higher aerobic colony counts were found in samples recovered from the wider bed space (zone 3) and staff toilet area (zone 6; Table 2). **The presence of moisture protects microorganisms against dehydration, and so both areas are conducive to the survival and persistence of bacteria, particularly gram-negative organisms (Table 3). Of the zones located outside of the isolation room, the staff toilet area was also the most likely to be contaminated with MRSA.**

Hands play an important role in healthcare-associated infection. They can transfer bacteria from a colonized patient to an uninfected patient either directly or via an environmental surface. Inadequate hand hygiene after patient contact and/or after contact with patient surroundings can contaminate local environmental surfaces and help to spread potential pathogens throughout the ward environment.¹⁷ Much emphasis is placed on improving staff hand hygiene compliance, but patient hand hygiene should also be encouraged.

In the gastrointestinal ward (as in the ICU), high numbers of bacteria were found in samples recovered from the zone closest to the patient (zone 1), and comparatively few were found in samples recovered from sites with high levels of staff contact within the near-patient environment (zone 2; Table 2). However, in contrast with patients in the ICU, who were generally bed bound, patients in the GI ward readily moved around their bed space and elsewhere within the ward. Reducing the level of pathogens within the critical care setting reduces the level of pathogens on the hands of staff.¹⁶ Patient

TABLE 4. Distribution of Potential Pathogens within a Gastrointestinal Medical Surgical Ward

Sample zone	Surfaces from which target organisms were recovered, %				
	MSSA	MRSA	VSE	VRE	Gram-negative rods ^a
4-bed bay					
Near-patient environment (zone 1; <i>n</i> = 329)	11.5	1	23	0.3	4
Near-patient environment (zone 2; <i>n</i> = 396)	5	0.8	19	0.8	4.5
Patient toilet and shower area (zone 3; <i>n</i> = 196)	17	2	32	1.5	16
Wider bay environment (zone 4; <i>n</i> = 99)	9	1	14	0	26
Wider ward environment (zone 5; <i>n</i> = 325)	5	0.9	12	0	7
Staff toilet (zone 6; <i>n</i> = 128)	10	0	3	0	9
Single isolation room					
Patient bed area (zone 1; <i>n</i> = 93)	0	0	25	19	6
Near-patient environment (zone 2; <i>n</i> = 97)	3	0	8	8	2
Wider room environment (zone 3; <i>n</i> = 132)	1.5	0	4.5	3	6
En suite toilet and shower area (zone 4; <i>n</i> = 165)	0.6	0.6	19	9	11.5
Outside single room (zone 5; <i>n</i> = 66)	3	0	17	4.5	4.5

NOTE. MRSA, methicillin-resistant *Staphylococcus aureus*; MSSA, methicillin-susceptible *S. aureus*; VRE, vancomycin-resistant enterococci; VSE, vancomycin-susceptible enterococci.

^a Including *Acinetobacter baumannii*.

mobility has predictable effects on the acquisition of organisms at patient contact sites, and reducing the environmental load should reduce the number of pathogens acquired from such surfaces by the patients themselves.

Zone 3, the patient toilet and shower area, was the most heavily contaminated zone within the GI ward (Table 2). Relatively few bacteria were recovered from surfaces associated with the toilet itself (eg, the toilet flush button), which implies that current cleaning protocols focus on surfaces traditionally considered high risk. The risk posed by unrecognized colonization has been discussed,¹⁸ and other sites with high patient contact (eg, shower head and door handles) demand equal attention during cleaning. Toilet and shower facilities should be considered a high-risk zone (Table 4), and all associated surfaces should be frequently cleaned. In addition, patients should be encouraged to clean their hands after using the toilet and when leaving and returning to their bed space.¹⁹ The transfer of bacteria from surface to hands (and vice versa) is increased in the presence of moisture.^{20,21} Patients (and staff) should be made aware that hand washing must be accompanied by effective hand drying.

Results from this study confirm that hand hygiene should be considered a core infection control measure for preventing the spread of healthcare-associated infections. However, in terms of cleaning, they also suggest that a hospital should not be considered a single entity and that different ward types should be treated as separate environments and cleaning protocols adjusted accordingly. In the ICU, bacteria are most likely to be on surfaces that are regularly touched by healthcare workers. Much emphasis is placed on the frequent and thorough cleaning of the near-patient environment, but the cleaning of staff high-contact zones located further from the patient is also important. On wards where patients are more mobile, cleaning programs should focus on patient contact

sites, particularly those associated with the bed (eg, call button) and toilet and shower areas. However, additional cleaning does not necessarily mean improved cleaning, and it is imperative that the efficacy of cleaning protocols is validated and continually assessed.

Over the course of the study, 576 patients were admitted to the ICU, and 693 were admitted to the GI ward. Sampling was conducted in and around the bed space of 99 (17%) and 67 (9.5%) patients, respectively. Only sampled bed spaces were zoned, and not all surfaces within each zone were sampled. Furthermore, the sampling was performed in an ICU and general ward of one hospital only. Additional studies are required to assess whether the findings are typical of the wards in question and to confirm that, to reduce the spread of bacteria, cleaning programs need to be tailored to particular ward environments and designed to interrupt ward-specific routes of dissemination.

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