real-time feedback to environmental services personnel (eg, recleaning of sites with elevated ATP values could be required).

Our study has several limitations. First, only 1 hospital was studied, and the sample size was moderate. Additional studies are needed in other facilities. Second, the ATP cutoff values used for classification of surfaces as clean have not been validated for monitoring of CDI rooms. However, the cutoff value that was chosen has been used by other investigators.[6] Third, the surface area covered with each ATP swab in our study was greater than the surface area recommended on the package insert, because we chose to sample the same surface areas routinely selected for environmental cultures in our facility. However, this modification would not change our primary conclusion that negative ATP readings are predictive of negative cultures for *C. difficile*. Fourth, because the culture swabs were collected after the same surfaces were sampled for ATP detection, it is possible that some *C. difficile* spores were removed, and the number of positive sites could be underestimated. Finally, there is a need to evaluate whether other common methods for monitoring environmental cleaning (eg, fluorescent markers) are also useful to assess the effectiveness of CDI room disinfection.

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Infection Prevention and Control in the Intensive Care Unit: Open versus Closed Models of Care

In the intensive care unit (ICU), our sickest patients receive our most invasive treatments and are therefore highly vulnerable to hospital-acquired infection.[1,2] Up to one-third of ICU patients develop infectious complications of care,[1] with associated increases in morbidity, mortality, and healthcare costs.[3] Earlier research has indicated substantial heterogeneity in uptake of infection prevention best practices in North American hospitals,[4,5] and this variability may also exist in ICUs.[6] We hypothesized that ICU system-level characteristics, including closed model of care, academic affiliation, and availability of a dedicated infection control practitioner (ICP), may be associated with improved infection prevention practices.

During July 2011, we conducted a province-wide survey of nurse directors in ICUs across Ontario, Canada (population, 12 million). We developed a 77-item questionnaire to broadly capture ICU structures and processes relevant to infection prevention. The questionnaire was developed (item generation and reduction) by the authors and was further improved through pilot and sensibility testing by 3 ICU nurse directors and 2 ICPs.[7] It was then distributed via e-mail by the Ontario Ministry of Health and Long-Term Care Critical Care Secretariat to nurse directors of all ICUs. A second e-mail was sent to nonrespondents 2 weeks later. Approval was granted by the research ethics board at Sunnybrook Health Sciences Centre in Toronto, Canada. Analyses were conducted

TABLE 1. Infection Prevention and Control in Open versus Closed Intensive Care Units (ICUs)

ICU characteristic	Open ICUs (n = 48)	Closed ICUs (n = 82)	P[a]
General characteristic			
Academic affiliation	13 (27)	44 (54)	.003
Median no. of beds (IQR)	7 (5–9)	15 (11–21)	<.001
Patient characteristic			
Receipt of mechanical ventilation	26 (54)	76 (93)	<.001
Medical	42 (88)	64 (78)	.18
Surgical	38 (79)	59 (72)	.36
Trauma	13 (27)	21 (26)	.85
Cardiac surgery	2 (4)	14 (17)	.03
Coronary	31 (65)	45 (55)	.28
Neuro/neurosurgical	1 (2)	16 (20)	.004
Burns	2 (4)	10 (12)	.13
Transplant	2 (4)	7 (9)	.34
Pediatric	7 (15)	11 (13)	.85
Nurse staffing			
Day bed : nurse ratio, median (IQR)	2.5 (1.8–3.5)	1.4 (1.3–1.8)	<.001
Night bed : nurse ratio, median (IQR)	2.5 (2.1–3.5)	1.5 (1.3–1.9)	<.001
Agency/float nurses,[b] median (IQR)	2.5 (1–10)	2 (1–5)	.53
Infection prevention and control characteristics			
Structural characteristics			
Beds in single rooms, median (IQR)	77 (40–100)	100 (65–100)	.01
Separate clean and soiled utility rooms	45 (94)	79 (96)	.50
Separate patient and visitor entrances	4 (8)	31 (38)	<.001
Infection prevention staffing			
Dedicated infection prevention staff	14 (30)	53 (65)	<.001
Infectious diseases consultant on site	25 (54)	78 (96)	<.001
Hand hygiene			
Alcohol hand rinse at all bedsides	29 (62)	56 (69)	.39
Sinks dedicated for hand hygiene	18 (43)	30 (39)	.72
Hands-free activation for all sinks	7 (17)	21 (28)	.18
Sinks close enough to splash beds	5 (11)	9 (11)	1.00
Hand hygiene education for all staff	43 (93)	78 (98)	.27
Hygiene posters in visitor and patient areas	42 (91)	66 (83)	.17
Infection control policies			
MRSA screening at admission	45 (98)	79 (100)	.19
MRSA screening at discharge	9 (20)	27 (34)	.08
VRE screening at admission	43 (93)	75 (96)	.50
VRE screening at discharge	10 (22)	28 (35)	.11
Contact precautions			
For *Clostridium difficile*	46 (100)	78 (99)	.44
For all diarrhea	44 (96)	76 (97)	.59
For fever and respiratory symptoms	44 (98)	74 (96)	.62
For all fever	21 (46)	38 (50)	.64
Off duty policy for staff when ill	42 (91)	74 (95)	.44
Environmental cleaning			
Bed : FTE cleaner ratio, median (IQR)	4.5 (3.5–6.0)	6.3 (4.3–8.0)	.001
Bed spaces cleaned			
More than once per day	7 (15)	10 (13)	
Once per day	39 (85)	64 (82)	.47
Less than once per day	0 (0)	4 (5)	
Special cleaning for *C. difficile* bedspaces	45 (100)	75 (96)	.18

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TABLE 1 (*Continued*)

ICU characteristic	Open ICUs (n = 48)	Closed ICUs (n = 82)	P[a]
Antibiotic stewardship			
Antibiotic restriction policies	5 (11)	32 (41)	<.001
Audit and feedback to prescribers	10 (22)	41 (53)	.001
Local ICU guidelines for infections	5 (11)	34 (44)	<.001
Standard orders for ICU infections	6 (13)	18 (23)	.19
Quality improvement leadership			
Physician-led quality improvement	17 (40)	56 (73)	<.001
Nurse-led quality improvement	11 (24)	39 (51)	.004
Morbidity and mortality rounds	17 (37)	40 (53)	.09
Infection preventability			
Strongly agree that nursing practices influence infection rates	25 (57)	49 (64)	.41
CLABSI best practices			
Hand hygiene	78 (100)	36 (86)	.0006
Chlorhexidine for antisepsis	77 (99)	31 (74)	<.0001
Use of a bundled approach	73 (94)	31 (74)	.002
Maximal barrier precautions	75 (96)	27 (64)	<.0001
Daily review for line removal	74 (95)	26 (62)	<.0001
Dedicated carts	71 (91)	22 (52)	<.0001
Avoidance of femoral site	59 (76)	25 (60)	.07
Checklists for best practices	61 (78)	19 (45)	.0003
VAP best practices[c]			
Head of bed elevation	72 (100)	24 (100)	
Use of a bundled approach	69 (96)	22 (92)	.43
Routine oral chlorhexidine	68 (94)	15 (63)	<.0001
Oral versus nasal intubation	61 (85)	18 (75)	.28
Daily spontaneous breathing trials	58 (81)	17 (71)	.32
Evacuation of subglottic secretions	40 (56)	7 (29)	.03

NOTE. Data are no. (%) of ICUs, unless otherwise indicated. CLABSI, central line–associated bloodstream infection; FTE, full-time equivalent; IQR, interquartile range; MRSA, methicillin-resistant *Staphylococcus aureus*; VAP, ventilator-associated pneumonia; VRE, vancomycin-resistant enterococci.

[a] P values reflect χ^2 tests of proportions or Wilcoxon rank-sum tests for continuous variables.

[b] Percentage of nursing shifts filled by nonpermanent nursing staff.

[c] Analyses of VAP best practices are limited to ICUs that perform mechanical ventilation.

using SAS, version 9.3 (SAS), at the level of the individual ICUs, because ICU characteristics, including leadership, procedures, and culture often vary among different ICUs within a single hospital. Multivariable logistic regression was used to examine the adjusted impact of 3 main predictors (closed ICU format, in which patients are transferred under the direct care of intensive care specialists; academic affiliation, defined as university affiliated vs other; and presence of a dedicated ICP) on the following 2 composite outcomes: routine use of all central line–associated bloodstream infection (CLABSI) best practices (in all ICUs), and routine use of all VAP best practices (in the subset of ICUs offering mechanical ventilation). The component CLABSI and VAP best practices included in these composite outcomes are listed in Table 1. Generalized estimating equations were used to account for potential intrahospital correlation of ICU characteristics.

Surveys were administered to nurse directors in 190 ICUs in 85 hospitals, and responses were obtained from 130 distinct ICUs (68%) from 74 hospitals (87%; a total of 1,712 ICU beds). Responding and nonresponding ICUs exhibited similar proportions of academic affiliation (42% vs 40%; P = .84). Most of these ICUs were capable of providing mechanical ventilation (78%), and collectively, they treated a broad range of critically ill patients (Table 1).

A closed ICU model was reported by 82 (63%) of the ICUs, and an open ICU model was reported by 48 (37%). The closed ICUs were generally larger than open ICUs (median [interquartile range], 15 [11–21] beds vs 7 [5–9] beds; P < .001), more likely to report an academic affiliation (54% vs 27%; P = .003), and more likely to treat patients who received mechanical ventilation (93% vs 54%; P < .001; Table 1).

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Staffing differed among closed versus open ICUs, with closed ICUs more likely to have an infectious diseases consultant on site, a dedicated ICP, and a lower bed-to-nurse ratio. Hand hygiene, surveillance, isolation, and cleaning policies were similar across closed and open ICUs. Antibiotic stewardship initiatives were more common in closed ICUs, as were morbidity and mortality rounds and nominated physician and nursing leads for quality improvement (Table 1). Rates of all CLABSI best practices and some VAP best practices were significantly higher in closed ICUs than in open ICUs (Table 1).

In a multivariable analysis that included closed ICU model, academic affiliation, and dedicated ICP, only closed ICU model was significantly associated with routine use of all major CLABSI best practices (odds ratio [95% confidence interval], 4.5 [1.8–10.8]; $P = .0009$) or all major VAP best practices (odds ratio [95% CI], 3.0 [0.9–10.2]; $P = .07$). Nurse staffing and ICU size were excluded from the model because of high collinearity with closed ICU designation.

This province-wide survey observed significantly higher use of best practices for infection prevention in closed ICUs than in open ICUs. Closed ICUs were more likely to use specific and bundled evidence-based practices to prevent VAP and CLABSI, were more likely to have identified quality improvement leadership, and were more likely to offer antimicrobial stewardship.

Earlier research has suggested that closed ICUs may offer advantages, including more efficient resource utilization, shorter length of stay and duration of mechanical ventilation, greater patient and family satisfaction, improved training of house staff, and greater confidence among nursing staff in clinical decision making.[8,9] Our survey indicates that these benefits may extend to improved use of infection prevention best practices.

There are a number of potential mechanisms by which closed ICU models may foster improved infection prevention. First, centralization of clinical leadership within a closed ICU may facilitate implementation of infection prevention measures; second, specialized training of closed ICU physicians may increase expertise in preventing infection in this unique population; and third, more efficient resource use in closed ICUs may enable greater attention to infection prevention. The association of closed ICU model with increased use of best practices must be interpreted with caution, given the potential influence of unmeasured confounders or measured differences in these ICUs (eg, number of beds and bed-to-nurse ratios). We were unable to evaluate the independent effects of these measured variables because of collinearity. Our study is also limited by reliance on self-reported survey data from a single provider group but is strengthened by the high response rate across an entire region and the richness of description across key infection prevention domains.

In summary, our population-based survey suggests that closed model ICUs may be preferable to open ICUs for optimizing infection prevention, but future research in other large jurisdictions is required to confirm this finding and to examine whether variability in ICU structures of care influences rates of critical care–associated infections.

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