American Journal of Infection Control 45 (2017) 746-9

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

Major Article

Heat map for data visualization in infection control epidemiology: An application describing the relationship between hospital-acquired infections, Simplified Acute Physiological Score II, and length of stay in adult intensive care units

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Key Words:
Surveillance
Intensive care unit
Hospital-acquired infections
Length of stay
SAPSII
Heat map
Data visualization

Background: Hospital-acquired infections (HAIs) in intensive care units (ICUs) are associated with increased length of stay (LOS). The objective of this study was to graphically describe by heat mapping LOS of patients hospitalized in ICUs related to the occurrence of HAI and severity at admission measured by the Simplified Acute Physiological Score II (SAPSII).

Methods: Adult patients hospitalized in ICUs of Lyon University Hospitals (France) were included in an active standardized surveillance study of HAI from January 1, 1995-December 31, 2012. Surveillance included adult patients aged ≥18 years hospitalized ≥2 days. Patient follow-up ended at ICU discharge or death. LOS was calculated in days from differences between dates of entry and discharge from ICUs. HAIs recorded were pneumonia, bacteremia, and urinary tract infection. The heat map was designed with a spreadsheet software.

Results: A total of 34,694 patients were analyzed. Among infected patients, 72.3% had 1 infected site (IS), 23% had 2 ISs, and 4.7% had 3 ISs. Median LOS was 24 days in infected patients (20.4 days among patients with 1 IS, 34.2 days among patients with 2 ISs, and 45.3 days among patients with 3 ISs) and 5 days in noninfected patients ($P < .001$). Two groups of multi-infected patients with long LOSs were identified with the heat map.

Conclusions: The heat map facilitated easy-to-implement semi-quantitative visualization of increasing LOS through the SAPSIIs and number of ISs.

Hospital-acquired infections (HAIs) in intensive care units (ICUs) are associated with increased length of stay (LOS),[1] a determinant or consequence of HAI. Before calculation of attributable excess LOS because of HAI, it would be interesting to report detailed descriptive data on the relationship between occurrence of HAI and LOS. Indeed, most descriptions summarized the information by showing overall means or medians. More accurate descriptions are warranted.

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Conflicts of interest: None to report.

0196-6553/
http://dx.doi.org/10.1016/j.ajic.2017.02.012

Table 1
Median length of stay (days) of patients included in the hospital-acquired infection surveillance program in intensive care units at Lyon University Hospitals, 1995-2012

No. of infections	Site	SAPSII category									
		11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	≥91	Total
0	N/A	3.5	4	4.8	5.2	5.7	6	6.2	6.2	4.6	5
1	BAC	14.2	18.3	18.6	19.2	16.2	17.6	20	21	21.3	18.2
	UTI	13	13.8	17.2	19	21.6	18.7	20.4	25	22.5	18.2
	PNE	17.3	22.3	22.4	22.5	20	21.4	21.1	23.8	25.2	21.8
2	UTI-BAC	11.5	26.3	39	24.5	26	26	16.5	33	31	26.9
	PNE-BAC	26	29.5	29.5	36	30	34.5	45	39.7	48	33.9
	PNE-UTI	38	38.2	36.6	34.4	39	30	35	36	48.5	35.7
3	PNE-BAC-UTI	51.5	47	52.3	42.7	41	44	46	43	94	45.3

BAC, bacteremia; *N/A*, not applicable; *PNE*, pneumonia; *SAPSII*, Simplified Acute Physiological Score II; *UTI*, urinary tract infection.

The Simplified Acute Physiological Score II (SAPSII) can predict in-hospital mortality.[2] Because the risk of HAI is related to duration of exposure, interaction between SAPSII, number of infections, and LOS deserves further descriptive analysis.

Heat maps have been drawn to graphically describe the relationship between 3 variables as 2-dimensional figures. This representation is reflected in large epidemiologic databases on community infections.[3,4] However, they are considered less often in HAI epidemiology, especially with large databases and despite some published results.[5] Large surveillance networks of HAI offer the opportunity of such stratified analyses.

The study objective was to graphically describe by heat mapping LOS of patients hospitalized in ICUs in relation to the occurrence of HAIs and clinical severity at admission as measured by the SAPSII.

MATERIALS AND METHODS

Adult patients hospitalized in ICU of Lyon University Hospital (France) were included in an active standardized surveillance study of HAI from January 1, 1995-December 31, 2012, as part of the voluntary national surveillance network, Réseau d'alerte, d'investigation et de surveillance des infections nosocomiales en réanimation (REA-RAISIN), since 2004.[6] Surveillance included all adult patients aged ≥18 years hospitalized ≥2 days in 12 participating units. Patient follow-up ended at ICU discharge or death. The study was reviewed and approved by the institutional review board Comité de Protection des Personnes SUD-EST II. No patient consent was necessary for this study.

LOS was calculated in days from differences between dates of entry into and discharge from ICUs. HAIs were included when they occurred ≥2 days after ICU admission. HAIs recorded during surveillance were hospital-acquired pneumonia (PNE), hospital-acquired bacteremia (BAC), and hospital-acquired urinary tract infection (UTI). Definitions of these infections matched to those of the European Centre for Disease Prevention and Control.[7] Only the first infection in each of these 3 sites was analyzed. Numbers of sites infected were 0, 1, 2 (≥1 BAC and ≥1 PNE; or ≥1 BAC and ≥1 UTI; or ≥1 PNE and ≥1 UTI), or 3 (≥1 PNE, ≥1 BAC, and ≥1 UTI). Patients were stratified by the SAPSII, calculated at the 24th hour after admission and taking into account the worst values of variables needed to obtain scores within that time period. The SAPSIIs ranged from 0-163. Data were censored at December 31, 2012, because UTI were not part of the surveillance thereafter.

Median LOS was stratified into SAPSII categories (0-10, 11-20, 21-30, 31-40, 41-50, 51-60, 61-70, 81-90, ≥91), estimated for each site, and number of infections, with comparison by Mann-Whitney *U* or Kruskal-Wallis tests. Crude ICU mortality proportion was compared between infected and noninfected patients with χ^2 test. The SAPSII categories with a majority of median LOS calculated with 5 patients or less were censored in the results. The heat map was designed with Microsoft Excel 2013 (Microsoft, Redmond, WA), assigning yellow for shorter LOS and red for longer LOS, with a 3-color gradient. The data were analyzed by IBM SPSS Statistics 20 (IBM, Armonk, NY).

RESULTS

A total of 34,694 patients, accounting for 388,458 patient days of hospitalization in ICUs, were analyzed, with an average number of 1,927 (range, 378-2,700) patients included per year. Men comprised 63.6% of patients, and mean age was 59.4 ± 17.4 years. The mean SAPSII was 42.6 ± 19.2, and severity at admission increased with time from 33.7 ± 17.9 in 1995 to 49.9 ± 20.2 in 2012 ($P < .001$). The overall HAI incidence proportion was 16% (n = 5,543), and the incidence density rate was 14.3 per 1,000 hospitalization days and ranged from 9.3% and 11.3 per 1,000 days for SAPSIIs <30 to 20.8% (15.3 per 1,000 days) for SAPSIIs ≥50 ($P < .001$).

Among infected patients, 72.3% had 1 infected site (n = 4,010), 23% had 2 infected sites (n = 1,273), and 4.7% had 3 infected sites (n = 260). Among patients with 1 infected site, 57.2% (n = 2,295) had PNE, 30.5% (n = 1,224) had UTI, and 12.2% (n = 491) had BAC. Among patients with 2 infected sites, 51.4% (n = 654) had UTI and PNE, 33.4% (n = 425) had BAC and PNE, and 15.2% (n = 194) had UTI and BAC. Overall in-hospital ICU mortality was 18.6% (6,469 deaths). The ICU mortality was 30.3% among infected patients and 16.4% among noninfected patients ($P < .001$).

The median LOS was 24 days (interquartile range, 25) in infected patients and 5 days (interquartile range, 6 days) in noninfected patients ($P < .001$) (Table 1). Among noninfected patients, the median LOS ranged from 3.3 days for SAPSIIs ≤10 to 6.2 days for SAPSIIs from 81-90. Among infected patients, the median LOS ranged from 17.2 days for SAPSIIs from 11-20 to 27.8 days for SAPSIIs ≥91 ($P < .001$). The median LOS was 20.4 days among patients with 1 infected site (BAC: 18.2 days; UTI: 18.2 days; PNE: 21.8 days), 34.2 days among patients with 2 infected sites (UTI and BAC: 26.9 days; PNE and BAC: 33.9 days; PNE and URI: 35.7 days), and 45.3 days among patients with 3 infected sites ($P < .001$). Figure 1 reports the LOS according to number and type of HAI and SAPSII category as a heat map. The category 0-10 was censored because of the lack of data. Two groups of multi-infected patients with long LOSs were identified: those with low SAPSIIs and those with very high SAPSIIs at admission.

DISCUSSION

The objective was to report the added value of data visualization and describe relationships between SAPSII, HAI, and LOS in ICU patients. The inclusion period allowed for the description of LOS with >34,000 patients. We observed that median LOS was higher in infected patients than noninfected patients and increased with higher SAPSII and number of infected sites. These results are consistent with medical literature, but subgroups were identified by graphical visualization. The median LOS was also different for each site of infection, with greater LOS for PNE and lower LOS for BAC.