CONCISE COMMUNICATION

Denominator Matters in Estimating Antimicrobial Use: A Comparison of Days Present and Patient Days

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Patient days and days present were compared to directly measured person time to quantify how choice of different denominator metrics may affect antimicrobial use rates. Overall, days present were approximately one-third higher than patient days. This difference varied among hospitals and units and was influenced by short length of stay.

Infect Control Hosp Epidemiol 2018;39:612–615

Antimicrobial stewardship programs (ASPs) require robust assessments of antimicrobial use (AU) to demonstrate impact.[1] The preferred metric for AU is days of therapy (DOT) because of several advantages described previously.[2–4] One DOT is counted when a single antimicrobial agent is administered on a calendar day regardless of the number of administrations, resulting in whole day counts even for partial days of exposure.[2] When DOTs are aggregated, an AU rate is calculated over a denominator of person time at risk.[5] Days of stay on an inpatient unit are considered person time at risk for hospital antimicrobial exposures.

Traditionally, person time has been measured in patient days, a manual or electronic count of the number of patients in the location measured at the same time each day.[6] This metric may miss a partial day of patient exposure either at the beginning or end of a patient stay depending on the time of the daily count. Therefore, the National Healthcare Safety Network (NHSN) AU Option recently introduced a new metric termed "days present" as an alternate measure of person time to capture partial days in hospital locations.[7] Days present is the count of calendar days when a patient is present in the given location for any portion of the calendar day. Days present calculations are challenging because they require electronic capture of continuous admission–discharge–transfer (ADT) data and extensive data cleaning.[4] The impact of using the days present metric on hospital- and unit-level estimates of person time at risk has not been described previously. In this study, we aimed to compare patient days and days present to a "gold standard" of person time to quantify how choice of denominator may affect AU rates.

METHODS

We analyzed bed flow data from 5 community hospitals and 2 academic medical centers that participated in the Benefits of Terminal Room Disinfection Study from April 2012 to July 2014.[8] Data from inpatient units were included in the analysis, and emergency department, observation, and procedural unit data were excluded. Bed flow data were prospectively validated using samples of manually documented patient movements. Bed flow data included date–time of room entry and exit measured to the minute. Duplicate room entries were excluded. Extremely short unit stays of <2 hours were excluded because many of these events represented administrative actions and not true patient movements upon validation of bed flow data. Unit type was defined by local infection preventionists using NHSN definitions.[9]

Person time was calculated by subtracting date–time of room exit from date–time of room entry. Patient days were calculated using a midnight census count. Unit-level days present were counted if the patient was on an inpatient unit for any portion of a calendar day. When aggregated at the hospital level, an individual patient counted 1 day present on each calendar day; between-unit transfers did not result in double counting for hospital-level estimates, as specified in the NHSN AU option.[7] Percent relative differences (RDs) for patient days and days present were compared to person time among hospitals and units. The RDs were also calculated between days present and patient days.

RESULTS

More than 1.7 million patient days were evaluated during the 28-month period (Table 1). Median length of stay was 2.9 days per stay (interquartile range [IQR], 2.5–4.9) among the 7 hospitals and 3.5 days per stay (IQR, 2.8–4.6) among the 120 hospital units. For the hospital-level calculations, patient days were close underestimates of person time, whereas days present calculations overestimated person time (median RD, 33%; IQR, 24%–37%). Compared with community hospitals, the 2 academic centers had larger patient volumes, longer length of hospital stay, higher numbers of between-unit transfers, and lower RD comparing days present to person time. A hypothetical exercise applying these hospital-level denominators to a DOT numerator is provided in the Supplemental Material.

In unit-level analyses, days present also overestimated person time. However, the magnitude of the RD differed by unit type. The highest RDs were seen in unit types with short stays and historically lower AU (eg, cardiology step-down units and labor and delivery units). The lowest RDs were seen in unit types with long stays (eg, bone marrow transplant units and burn units).

TABLE 1. Relative Differences comparing Days Present and Patient Days Among 7 Hospitals, 2012–2014[a]

	No. of Units	No. of Hospital/ Unit Stays	Transfers in From Another Unit, No.	Transfers From Another Unit Per Total Unit Stays, %	Average Length of Stay, d	Patient Days	Days Present	Person Time, d	Relative Difference (Patient Days to Person Time, %)	Relative Difference (Days Present to Person Time, %)	Relative Difference (Days Present to Patient Days, %)
Hospital											
1C	13	53,505	872	2	2.46	129,524	182,967	129,623.63	− 0.08	41.18	41.26
2C	11	82,453	1,834	2	2.31	212,896	293,839	214,366.31	− 0.69	37.33	38.02
3C	6	35,066	545	2	2.88	96,439	131,426	98,241.28	− 1.87	34.41	36.28
4C	6	28,918	672	2	2.83	84,555	113,417	85,118.65	− 0.67	33.47	34.13
5C	9	53,243	769	1	3.59	171,001	223,877	173,577.62	− 1.51	29.41	30.92
6A	36	114,443	5,713	5	4.95	462,920	576,412	465,535.10	− 0.56	23.95	24.52
7A	39	128,593	6,484	5	5.15	543,616	671,546	541,068.76	0.47	24.00	23.53
Mean (SD)		70,889 (38,770)	2,413 (2,562)	3	3.45 (1.17)	242,993 (184520)	313,355 (222,097)	243,933.05 (183,818.72)	− 0.70 (0.80)	31.96 (6.53)	32.67 (6.72)
Median (IQR)		53,505 (35,066 – 114,443)	872 (672 –5,713)	2	2.88 (2.46–4.95)	171,001 (96,439–462,920)	223,877 (131,426–576,412)	173,577.62 (98,241.28–465,535.10)	− 0.67 (−1.51 to −0.8)	33.47 (24.00–37.33)	34.13 (34.52–38.02)
Unit Type											
Nursery	2	9,885	206	2	1.56	17,707	27,557	17,894.85	− 1.06	54.57	55.63
Labor and delivery	5	53,417	885	2	1.67	96,340	147,946	99,203.44	− 2.97	50.59	53.57
Cardiology step down	1	6,013	173	3	1.88	11,484	17,495	11,331.76	1.33	53.67	52.34
Rehabilitation unit	1	1,686	2	0	2.27	3,925	5,611	3,829.63	2.43	45.39	42.96
Cardiac ICU	3	6,066	223	4	2.59	15,479	21,531	15,893.3	− 2.68	36.42	39.10
Medical/Surgical ICU	3	17,051	860	5	2.79	47,175	64,147	48,146.71	− 2.06	33.92	35.98
Step down surgery	4	15,381	780	5	2.87	44,864	60,193	44,859.44	0.01	34.18	34.17
Cardiac ICU	1	3,548	205	6	3.17	11,095	14,631	11,257.74	− 1.47	30.40	31.87
Cardiothoracic surgery ICU	3	5,265	568	11	3.03	16,499	21,745	16,412.88	0.52	32.32	31.80
General medical or surgical ward	51	263,763	6,609	3	3.51	892,332	1,155,360	893,330.21	− 0.11	29.36	29.48
Cardiology ward	4	19,589	597	3	3.60	70,331	89,833	70,468.04	− 0.19	27.53	27.73
Neurologic ICU	3	7,098	619	9	3.64	26,037	33,111	25,965.92	0.27	27.44	27.17
Surgical ICU	4	6,782	669	10	3.99	27,061	33,814	27,342.19	− 1.04	23.92	24.95
Pediatrics	5	19,336	969	5	4.12	77,280	96,517	77,188.29	0.12	25.01	24.89
Medicine step down	2	3,113	283	9	6.38	13,552	16,661	13,693.86	− 1.05	21.89	22.94
Medical ICU	3	5,552	478	9	4.57	25,418	30,948	25,882.26	− 1.83	19.93	21.76
Cardiothoracic surgery step down	1	3,701	323	9	4.94	17,454	21,141	17,324.13	0.74	21.87	21.12
Oncology	4	14,629	414	3	5.11	73,802	88,410	73,734.04	0.09	19.89	19.79
Neurology ward	5	14,917	808	5	6.00	76,315	91,011	76,297.17	0.02	19.28	19.26
Pediatric cardiac unit	1	688	50	7	5.60	3,877	4,565	3,854.48	0.58	18.33	17.75
Pediatric ICU	6	12,218	1,014	8	9.24	67,652	79,624	68,126.18	− 0.70	17.00	17.70
Psychiatry ward	2	3,358	15	0	9.22	29,812	33,031	29,935.21	− 0.41	10.38	10.80
Bone marrow transplant unit	2	1,856	93	5	11.44	19,966	21,820	20,025.92	− 0.30	8.99	9.29
Burn ICU	1	1,309	46	4	11.87	15,494	16,782	15,533.7	− 0.26	8.06	8.31
Mean (SD)		20,676 (52,922)	704 (1,299)	3	4.79 (2.93)	70,873 (177,074)	91,395 (229,543)	71,147.14 (177,273.10)	− 0.42 (1.23)	27.93 (13.09)	28.35 (13.20)
Median (IQR)		6,424 (3,453–15,149)	446 (189–794)	7	3.81 (2.83–5.80)	25,728 (15,487–68,772)	31,990 (19,318–84,017)	25,924.09 (15,713.50–69,297.11)	−0.225 (−1.06 to 0.20)	26.225 (19.59–34.05)	26.06 (19.53–35.08)

NOTE. C, community hospital; A, academic hospital; IQR, interquartile range; ICU, intensive care unit; SD, standard deviation.

[a]Relative differences were calculated as follows: relative difference between days present and person time = (days present – person time)/person time. Average length of stay was calculated using person time.

TABLE 2. Antimicrobial Use Denominator Metric Summary

Denominator Metric Term	Definition	Data Required	Advantages	Disadvantages
Patient Days	A manual or electronic count of the number of patients in the given location measured at the same time each day.	One time per day census count	• Existing unit- and hospital-level estimates are already available for most hospitals. • Actively used by infection prevention teams • Administrators and clinicians are familiar with the metric. • Can be captured manually, if needed	• Patients may receive antimicrobials during a calendar day when they are not counted in the denominator metric. • Generally, not used for patient level analyses because counts are linked with locations instead of patients • Manual versus electronic methods may fail to standardize between hospitals. • Cannot be used in the NHSN AU option to compare with national data
Days Present	Electronic count of calendar days when a patient is present in the given location for any portion of the calendar day.	Continuous, electronic patient movement data	• Aligns with days of therapy numerators, which also capture partial days • Can be used in patient level analyses of length of stay and AU • Can be reported to the NHSN AU Option, allowing access to national data comparisons • May result in less manual daily work for frontline antimicrobial stewards and infection preventionists	• Cannot be captured manually • Requires additional information technology resources to capture, clean, validate, and report • Administrators and clinicians unfamiliar with the metric • Overestimates time at risk • Highly influenced by patients with short length of stay

NOTE. NHSN, National Healthcare Safety Network; AU antimicrobial use.

DISCUSSION

To our knowledge, this is the first comparative description of 2 denominators used to represent patient time at risk for antimicrobial use. Patient days, the traditional infection prevention denominator that counts at a single time each calendar day, may miss a partial day at risk on the day of admission or discharge, depending on the time of the daily census count. The newer days-present metric attempts to address this by counting all partial days. When aggregated, the additional time resulting from partial days increased AU rate denominator counts substantially. In our analysis, days present counts were approximately one-third higher than person time rounded to the nearest minute. Relative differences varied among hospitals and units and was highly correlated to length of stay.

Our findings have important implications for AU assessments. First, AU estimates using days present will be substantially lower than those using patient days. Thus, stewards need to carefully delineate days present versus patient days when interpreting and time-trending local data and when comparing local AU estimates to published literature or publically available AU estimates. Similarities in these terms and abbreviations may cause confusion. Second, the impact of short-stay patients has implications for hospital and unit comparisons. The presence of extra time in aggregated days present estimates will result in lower AU estimates in locations that care for patients with short stays. High-volume units with short stays (eg, labor and delivery wards and nurseries) have been considered lower-risk areas for antimicrobial exposure, but these had the highest RDs in our study. Stenejhem et al[10] described how the inclusion of these "miscellaneous" units inflated facility-wide denominators and affected the utility of facility-level comparisons; ultimately, they decided to exclude those units when benchmarking. Similarly, the NHSN AU SAARs (standardized antimicrobial administration ratios) exclude all units except general medical/surgical wards and medical/surgical intensive care units.[7] Eliminating units from analyses limits information gained about these patient populations and excludes them from assessment for improvement opportunities. Third, we observed that the RDs between patient days and days present varied among hospitals and that academic hospitals had lower RDs. We hypothesize that this observation is related to complex case mix and its association with longer length of stay. Risk adjustment methods for hospital benchmarking may help improve comparisons; however, the large effect from length of stay may be difficult to fully overcome with risk adjustment.

The advantages of the days present metric include the ability to participate in the NHSN AU option and access national data for comparisons. Alternatively, patient days are readily available, actively used by infection prevention, and do not require additional resources from information technology (Table 2). Individual hospitals should choose a single AU denominator metric based on their available resources and needs, then standardize terminology to most effectively interpret and externally share analyses of ASP impact.

This study has several limitations. The 7-hospital study sample may not be large enough to fully describe the comparisons. Included hospitals are in the southeastern United States and may differ from hospitals in other geographic locations and practice settings. Existing data within the NHSN could be used to validate these findings.

In summary, days present denominators increased days at risk estimates by approximately one-third when compared with patient days. This effect differed among hospitals and units and was highly influenced by short length of stay.

ACKNOWLEDGMENTS

Financial support: The Benefits of Terminal Room Disinfection study was funded by the Centers for Disease Control and Prevention Epicenters Program (grant no. 1U54C000164 to D.J.S.). R.W.M. was supported by the Agency for Healthcare Research and Quality (AHRQ grant no. K08 HS023866). D.J.A. was supported by the National Institutes of Health (NIH grant no. K23 AI095357).

Potential conflicts of interest: All authors report no conflicts of interest related to this article.

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Received October 23, 2017; accepted February 11, 2018

0899-823X/2018/3905-0016. DOI: 10.1017/ice.2018.54

SUPPLEMENTARY MATERIAL

To view supplementary material for this article, please visit https://doi.org/10.1017/ice.2018.54.

REFERENCES

1. Pollack LA, Srinivasan A. Core elements of hospital antibiotic stewardship programs from the Centers for Disease Control and Prevention. *Clin Infect Dis* 2014;59(Suppl 3):S97–S100.
2. Polk RE, Fox C, Mahoney A, Letcavage J, MacDougall C. Measurement of adult antibacterial drug use in 130 US hospitals: comparison of defined daily dose and days of therapy. *Clin Infect Dis* 2007;44:664–670.
3. Morris AM, Brener S, Dresser L, et al. Use of a structured panel process to define quality metrics for antimicrobial stewardship programs. *Infect Control Hosp Epidemiol* 2012;33:500–506.
4. Moehring RW, Anderson DJ, Cochran RL, Hicks LA, Srinivasan A, Dodds Ashley E. Expert consensus on metrics to assess the impact of patient-level antimicrobial stewardship interventions in acute care settings. *Clin Infect Dis* 2017;64:377–383.
5. Ibrahim OM, Polk RE. Antimicrobial use metrics and benchmarking to improve stewardship outcomes: methodology, opportunities, and challenges. *Infect Dis Clin N Am* 2014;28:195–214.
6. National Healthcare Safety Network. MDRO Module. Centers for Disease Control and Prevention website. http://www.cdc.gov/nhsn/PDFs/pscManual/12pscMDRO_CDADcurrent.pdf. Updated January 2018. Accessed February 21, 2018.
7. National Healthcare Safety Network. Antimicrobial use and resistance (AUR) options. Centers for Disease Control and Prevention website. http://www.cdc.gov/nhsn/acute-care-hospital/aur/index.html. Updated February 8, 2018. Accessed February 21, 2018.
8. Anderson DJ, Chen LF, Weber DJ, et al. Enhanced terminal room disinfection and acquisition and infection caused by multidrug-resistant organisms and *Clostridium difficile* (the Benefits of Enhanced Terminal Room Disinfection Study): a cluster-randomised, multicentre, crossover study. *Lancet (London)* 2017;389:805–814.
9. Locations and descriptions and instructions for mapping patient care locations. Centers for Disease Control and Prevention website. https://www.cdc.gov/nhsn/pdfs/pscmanual/15locationsdescriptions_current.pdf. Published 2013. Accessed February 15, 2018.
10. Stenehjem E, Hersh AL, Sheng X, et al. Antibiotic use in small community hospitals. *Clin Infect Dis* 2016;63:1273–1280.