We analyzed the cycle threshold ($C_T$) of PCR surveillance MRSA swabs obtained from veterans. Lower $C_T$ on admission was associated with a positive culture from nasal swabs at discharge. Compared to PCR, direct plating of nasal swabs performed poorly, especially for patients with an elevated $C_T$. The $C_T$ is strongly correlated with quantitative nasal cultures. Clinical and infection control applications of the $C_T$ have yet to be defined and warrant further evaluation.

Screening for methicillin-resistant Staphylococcus aureus (MRSA) nasal colonization is done in an attempt to control the spread of MRSA within health care settings and prevent subsequent MRSA infection. The Veterans Health Administration (VHA) was an early adopter of active universal nasal MRSA colonization surveillance for all patients admitted to acute-care facilities, with many hospitals and states subsequently following this course (8, 13).

Most active surveillance programs rely on rapid detection methods using direct chromogenic agar cultures and/or real-time PCR to minimize delays in the identification and isolation of carriers in an attempt to prevent nosocomial transmission of MRSA. Although they are less costly, direct chromogenic agar cultures are insensitive compared to PCR (15, 22). Broth enrichment in tryptic soy broth (TSB) prior to plating has been shown to increase the sensitivity of chromogenic techniques but also increases the workload and the time to result, making this method problematic for routine use in the clinical microbiology laboratory (11). Therefore, PCR has become the gold standard in determining colonization status.

Few studies have evaluated the impact of nasal MRSA colonization burden and results of agar based screening tests. In 2009, Wolk et al. demonstrated that a lower MRSA colonization burden is associated with discordant screening tests (positive PCR test and negative agar test), and the MRSA cycle threshold ($C_T$) values for the concordant samples in the Xpert MRSA assay (Cepheid, Sunnyvale, CA) were statistically lower than those for discordant samples (21). In our study, we examined the variation between PCR and direct culture screening methods for nasal MRSA colonization among hospitalized veterans, compared the $C_T$ values for patients with discordant screening results at admission and discharge, and evaluated the quantitative abilities of the Xpert MRSA PCR assay.

In October of 2007, the VHA and the Centers for Disease Control and Prevention developed a MRSA bundle to be instituted in all United States VHA medical centers. The MRSA bundle utilized, in addition to other measures, active surveillance of nasal MRSA colonization for all patients admitted to the hospital, transferred between units, and discharged from the hospital. The Atlanta VA Medical Center (AVAMC) is a large tertiary-care medical center serving over 80,000 veterans. The patients admitted to the AVAMC are primarily male (~95%) and either Caucasian (~54%) or African American (~44%) with significant medical and surgical comorbidities. Like many VHA medical centers, admission and transfer screening is done with a PCR-based test, while discharge screening is done by directly plating nasal swabs onto chromogenic agar. Extranasal sites are not routinely screened for MRSA, and MRSA decolonization is rarely implemented.

MRSA screening at the AVAMC is performed using a double swab, one swab with two swab heads. (Copan swabs with liquid Stuart medium; Cepheid). Both swab heads are inserted (together) 1 cm into each nasal vestibule and rotated 4 revolutions while maintaining even contact with the nasal mucosa. Swabs are sent directly to the microbiology laboratory for immediate testing, with one swab being used for PCR or culture and the partner swab being saved as a backup. Admission and transfer screening is performed by the Xpert MRSA PCR assay according to the manufacturer’s instructions (which includes initial vortexing of the swab in the PCR cassette), and a $C_T$ from 15 to 36 is considered positive. Discharge screening cultures are performed by direct inoculation (without initial vortexing) onto Spectra MRSA chromogenic agar (Remel, Lenexa, KS) (16), as rapid detection is unnecessary upon discharge and culture is significantly less costly.

From October 2007 through January 2008, 2,237 admission or transfer MRSA nasal screens were performed at the AVAMC, and 369 (16.5%) were positive, corresponding to 272 patients with a positive admission and/or transfer screen (many admissions had multiple positive nasal screens). The $C_T$ value for all positive MRSA admission or transfer screens was recorded. A corresponding discharge nasal surveillance culture was performed for 181 of the 272 patients (the remaining 91 patients did not have a discharge nasal swab performed due to poor compliance with obtaining discharge swabs early in the implementation of the VHA MRSA Directive). Of the 181 patients with a positive admission or transfer screen, 62 (34.3%) had a negative discharge culture for MRSA. For these 62 MRSA-discordant patients (positive PCR test and negative agar test), 39 partner discharge swabs were available.
Five hospital-acquired MRSA infections (HAI) occurred during hospitalization of the 272 patient (1.84% of admissions). The admission $C_T$ of patients that developed a HAI was not different from that of patients that did not develop a HAI (25.5 versus 27.2; $P = 0.4674$). The very few HAI in this cohort limits our power to detect a significant difference between the two groups and warrants further evaluation with a dedicated case-control study.

To ensure that clinical factors (i.e., antibiotics) did not contribute to the discrepancies seen between admission/transfer PCR and discharge culture results, we analyzed partner nasal swabs by PCR and culture simultaneously. Partner swabs for 204 consecutive positive admission or transfer PCR screens were collected from January to May 2011 and directly inoculated onto Spectra MRSA agar; colonies were counted at 24 h and converted for all positive swabs, with a standard deviation of 5.0. Only 146/204 (71.6%) were positive by direct inoculation to Spectra MRSA agar. The mean $C_T$ of swabs that were positive by both PCR and direct agar culture was 25.6, compared to a $C_T$ of 31.4 for those that were positive by PCR and negative on direct inoculation ($P < 0.005$) (Fig. 1).

In an attempt to assess the quantitative capabilities of the Xpert MRSA assay, 76 PCR-positive admission partner swabs were placed into 500 μl of tryptic soy broth (Becton Dickinson Co., Sparks, MD) and vortexed for 10 s to simulate the initial step in the Xpert assay. Serial dilutions of the broth were spiral plated onto Spectra MRSA agar; colonies were counted at 24 h and converted to $\log_{10} \text{CFU/ml}$ (12). Using this method, 73/76 PCR-positive partner swabs grew MRSA. A strong correlation between $C_T$ and $\log_{10} \text{CFU/ml}$ was observed, with a Pearson’s correlation coefficient of $-0.89$ ($P < 0.0001$) (Fig. 2). The following linear regression line was fit to the data: $\log_{10} \text{CFU/ml} = 10.54 - 0.26C_T$.

Using a preexisting MRSA surveillance system, we have demonstrated that the MRSA $C_T$ on the Xpert MRSA assay is a reliable marker of nasal MRSA colonization burden, that direct plating of nasal swabs is a less reliable test for patients with a low MRSA nasal burden, and that a higher MRSA nasal burden is associated with subsequent positive nasal screens.

Nasal $S. aureus$ colonization clearly increases the risk of developing subsequent $S. aureus$ infections (3, 4, 6, 7, 18). Nasal colonization is now commonly being determined by PCR-based testing (1, 8, 9) due to its ease of implementation, reliability, and rapid results. An additional advantage of PCR-based tests is an easily obtained measure of quantification in the $C_T$. Quantification of nasal $S. aureus$ colonization was described over 50 years ago and has been linked to the persistently colonized state (14, 20), an increased risk of contamination of the environment (5, 17), an increased risk of infection (10, 19), and a higher likelihood that other body sites (besides the nares) are colonized (12). In those studies, $S. aureus$ carriage was quantified by labor- and time-intensive techniques not easily implemented in a clinical practice. Now, with an easily obtained and reliable measure of nasal quan-
tification, the clinical and infection control implications of nasal S. aureus burden can be further evaluated.

The Xpert MRSA assay targets the staphylococcal cassette chromosome mec (SCCmec)-orfX junction and does not specifically target the mecA gene. Because of this, methicillin-sensitive S. aureus (MSSA) isolates with empty cassettes may test positive with the Xpert MRSA assay. A recent report evaluated this phenomenon and reported a false-positive rate of 7.7% in positive nasal MRSA screens (2). We did not attempt to isolate MSSA from swabs that were PCR positive and culture negative, and this is a limitation of our study. However, the large discrepancy seen between PCR testing modalities and direct plating is not likely all due to this phenomenon. As our data demonstrate, negative results for direct culturing are most likely due to the inability of MRSA to grow on the Xpert media. Vortexing nasal swabs prior to plating greatly enhances culture results.

Direct plating, used by the AVAMC for all discharge cultures in an attempt to measure MRSA acquisition in the hospital, likely misses a significant proportion of patients with low-level MRSA nasal colonization, which calls into question the reliability of this protocol and its cost savings. The potential role of nasal MRSA quantification in infection control and clinical care is unknown and deserves further study.

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We have no potential conflicts of interest to declare.

REFERENCES