Performance of the BD GeneOhm™ MRSA Test Before and
During High-Volume Clinical Use

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ABSTRACT

We evaluated use of the BD GeneOhm™ MRSA (BD Diagnostics, San Diego, CA) real-time PCR assay for the detection of methicillin-resistant Staphylococcus aureus (MRSA) nasal colonization. The initial evaluation consisted of 403 paired nasal swabs and was done using the kit provided specimen preparation and an in-house lysis method that was specifically developed to accommodate large volume testing using a minimal amount of personnel time. One swab was placed into an achromopeptidase (ACP) lysis solution and the other was used for culture, then prepared according to the kit protocol. PCR was performed on both lysates with results compared to culture. The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of the PCR assay was 98%, 96%, 77%, and 99.7% with the kit lysate and 98%, 95%, 75% and 99.7% with the ACP lysate ($p = \text{NS}$). The second evaluation was done after implementation of all-admission surveillance using PCR with ACP lysis and a sampling of 1107 PCR negative samples and 215 PCR positive samples that were confirmed by culture. The results of this sampling showed a NPV of 99.9% and a PPV of 73.5% (prevalence = 6%), which were consistent with our initial findings. The BD GeneOhm™ MRSA assay is an accurate and rapid way to detect MRSA nasal colonization. When dealing with large specimen numbers, the ACP lysis method offers easier processing without negatively affecting the PCR assay sensitivity or specificity.
INTRODUCTION

Methicillin-resistant *Staphylococcus aureus* (MRSA) continues to increase in prevalence within United States hospitals and in the community (14, 26). Furthermore, the burden of MRSA in U.S. healthcare organizations is often underestimated due to the significant prevalence of unrecognized, asymptomatic colonization (21). The recognized ecologic niche of *S. aureus* is the anterior nares (30). Studies have shown that approximately 25-30% of the population is colonized with *S. aureus* and that 0.2-7% is colonized with MRSA (18, 23, 30). Nasal colonization with MRSA can serve as a reservoir for transmission and is also considered a risk for subsequent infection (5, 8, 10).

While the optimal method for controlling MRSA is currently unproven and continues to be debated, largely due to the fact that there is no well-designed randomized trial assessing the impact of active surveillance, many (including the Centers for Disease Control and Prevention [CDC]) advocate the use of active surveillance for MRSA carriers as an option to decrease spread in a setting where MRSA infection rates are not decreasing (3, 4). The use of culture based detection of MRSA with traditional media requires 48-96 hours for results (13, 22). A combination of molecular methods with culture decreases the time to results to about 24-40 hours (15). In contrast, the BD GeneOhm™ MRSA, formally called IDI-MRSA, (BD Diagnostics, San Diego, CA) real-time PCR assay offers identification of MRSA colonized patients in a rapid time of as little as 2 hours (4, 29). Also, this real-time PCR method recently has been compared to plating of samples to agar, and if any test (including PCR) was assumed to be a true positive, the sensitivity of culture was 62% for direct plating, which increased to 85% with broth enrichment, and the sensitivity of PCR was 95% (31). The prompt and sensitive detection of MRSA carrier status can allow for several infection control benefits. Firstly, a
MRSA colonized patient can be placed in contact isolation earlier and thus decrease the chance for nosocomial transmission (20). Secondly, the patient can take a decolonization regime to potentially reduce the likelihood of a subsequent MRSA infection. Thirdly, earlier determination of MRSA negative patients can minimize the isolation days for facilities practicing pre-emptive isolation. Finally, the greater sensitivity of PCR compared to culture identifies more patients colonized with MRSA.

Evanston Northwestern Healthcare, to enhance infection control, deployed a universal MRSA surveillance program testing all 40,000 annual admissions on August 1, 2005 that was the first of its kind in North America. The purpose of our work was to validate the alternative lysis procedure we developed for use with the BD GeneOhm™ MRSA real-time PCR assay that was used in this initiative, which was developed to facilitated processing 100 to150 nasal swabs a day by a single laboratory worker, and to evaluate the overall PCR test performance during high-volume clinical use.

**MATERIALS AND METHODS**

**Patient population and specimen collection.** Evanston Northwestern Healthcare (ENH) is a three hospital, 850–bed academic organization in the northern suburbs of Chicago, Illinois that is affiliated with Northwestern University’s Feinberg School of Medicine. Nasal samples were collected using pre-moistened (using the Aimes medium in the transport container), double-headed rayon tipped swabs (CultureSwab, BBL, Becton Dickinson, Sparks, MD) with both swabs rubbed inside the anterior nare of one side followed by the other, yielding a paired swab sample.
Initial investigation comparing the kit lysis procedure with our in-house achromopeptidase lysis method. On 22 separate days in May 2005 to July 2005, nasal specimens collected from patients before orthopedic surgery or upon admission to the Intensive Care Unit (ICU) were analyzed by culture and BD GeneOhm™ MRSA real-time PCR using two lysis methods.

High volume clinical use investigation using the in-house achromopeptidase lysis method. Universal surveillance for MRSA began on August 1, 2005. Nasal specimens were collected on all admissions and tested by BD GeneOhm™ MRSA real-time PCR using our achromopeptidase lysis method. On 12 separate days in November 2005 to December 2005 and 20 separate days in March 2006 to May 2006, all real-time PCR negative specimens were cultured. On consecutive days during May 5, 2006 through May 22, 2006 and November 13, 2006 through November 30, 2006, all real-time PCR positive specimens were cultured.

Culture for MRSA. One of the paired swabs from the nasal specimen was plated to Columbia-Colistin-Nalidixic acid Agar (CNA) with 5% sheep blood (Remel, Inc., Lenexa, KS) and incubated in 5% CO$_2$ at 35°C for 24 to 48 hours. For PCR positive and CNA culture negative samples, broth enrichment for additional S. aureus detection was performed. Swabs were stored refrigerated until being incubated in 1 ml of Thioglycollate Medium without indicator (Thio; BBL) or in 5 ml of Tryptic Soy Broth (TSB) with 6.5% NaCl (Remel) for 24 and 48 hours at 35°C that was then plated to CNA. S. aureus was identified by colony morphology and Staphaurex™ latex agglutination test (Murex Biotech Limited, Dartford, Kent, UK). Methicillin resistance was determined by testing colonies for the presence of the meca gene specifically by an in-house real-time PCR test (19).
Kit lysis procedure. Samples were processed following the BD GeneOhm™ MRSA assay protocol. Briefly, after plating, the swab was broken off into a tube containing sample buffer and vortexed for 1 minute. The entire cell suspension was then transferred to a lysis tube and centrifuged for 5 minutes. The supernatant was removed and 50 µl of fresh sample buffer was added. Then the sample was vortexed for 5 minutes followed by a brief centrifugation. Lastly, the samples were incubated at 95°C for 2 minutes. The samples were placed at 4°C and the supernatant was used directly in real-time PCR. After PCR, the samples were stored at -20°C.

Achromopeptidase lysis procedure. The second swab from the nasal specimen was broken off into a screw-top microcentrifuge tube containing 200 µl of 1 U/µl a chromopeptidase in 1x TE (10 mM Tris-HCl pH 8.0, 1 mM EDTA; Sigma-Aldrich, Co., St. Louis, MO). Swabs in the a chromopeptidase solution were vortexed for 5-10 seconds and the sample was incubated at 37°C for 15 minutes. Then samples were incubated at 99°C for 5 minutes. Only samples tested before August 1, 2005 were centrifuged at >10,000 x g for 1 minute (18), this step was subsequently removed as it was unnecessary (data not shown). The samples were placed at 4°C and the free fluid around the swab was used directly in real-time PCR.

Real-time PCR procedure. Real-time PCR reactions were performed following the manufacturer’s protocol. Each master mix tube was hydrated with 225 µl of dilu en. A 25 µl aliquot of the master mix was pipetted into SmartCycler reaction tubes and 2.8 µl of lysate was added. Real-time PCR was executed using the SmartCycler™ instrument (Cepheid, Inc., Sunnyvale, CA) with the BD GeneOhm™ MRSA assay PCR protocol. A positive control (supplied with the kit) and a negative control (kit sample buffer or a chromopeptidase solution) were included in each run. During the high-volume clinical testing all specimen lysates were
stored at 4°C and any with an unresolved result had the PCR reaction repeated during the final run of the day on these stored samples.

The PCR reagents contained within the BD GeneOhm™ MRSA assay were updated by GeneOhm Sciences in early 2006. The proprietary changes were validated by the company at external reference laboratories. After February 20, 2006, all testing was performed with the new (current) PCR reagents.

**In vitro testing comparison of lysis methods.** Ten-fold serial dilutions of clinically isolated MRSA strains were spiked directly into achromopeptidase lysis tubes and kit lysis tubes. Additionally, ten-fold serial dilutions of MRSA done in 1x TE buffer were spiked directly onto swabs in 10 or 20 µl aliquots and compared to determine the limit of detection from actual swabs for both Copan single swabs (kit recommended) and our selected double-headed swabs with both lysis methods.

The amount of time required for each lysis method was determined by documenting the time requirement to process patient nasal swabs just after breaking them into the tube through the time until the specimens were ready for PCR. The incubation times were removed from this total to determine the hands-on processing time. Two separate technologists, familiar with the kit method, were self-timed performing processing on two different batches of 14 samples.

Statistical analysis was done using the Chi square test. This retrospective assessment of the assay method performance analysis was approved by the institutional review board of Evanston Northwestern Healthcare.

**RESULTS**
In vitro testing before patient analysis found the real-time BD GeneOhm™ MRSA PCR assay to have an analytic sensitivity of approximately 2 CFU/PCR reaction for both lysis methods. Ten-fold serial dilutions of MRSA spiked directly onto swabs yielded a sensitivity of approximately 300 CFU/swab for both single swabs and double-headed swabs with both lysis methods (data not shown).

Time analysis of the processing required for 14 samples using the kit lysis method was 35 minutes and the achromopeptidase lysis method was 23 minutes. After subtracting the incubation time, the total hands-on time was calculated at 22 minutes for the kit lysis and 3 minutes for the achromopeptidase method (Table 2).

**Initial investigation comparing the kit lysis procedure with our in-house achromopeptidase lysis method.** A total of 403 nasal specimens were randomly selected from testing done between May 2005 to July 2005 where culture was compared to real-time PCR using both lysis methods. Directly plated or Thio broth-enriched culture identified 50 specimens (12.4%) with MRSA. PCR using the kit lysate compared to culture yielded 48 swabs positive for MRSA by both methods, 336 negative by both methods, 1 positive by culture only, 14 positive by PCR only, and 4 unresolved (0.99%) by PCR. The PCR assay gives definitive results with no need for interpretation. A sample’s result can be positive for MRSA, negative for MRSA with a valid internal control, or unresolved (internal control failure) that generally indicates some amount of PCR inhibition. There were 9 specimens (2.2%) with an initial PCR result of unresolved. For those samples the PCR reactions were repeated using the frozen lysate as recommended in the kit directions. On repeat PCR, 5 samples gave negative results and 4 samples remained unresolved, one of which contained MRSA in culture. Specimens with a repeated unresolved PCR result were excluded from statistical analysis. The sensitivity,
specificity, positive and negative predictive values are shown in Table 1. For 6 of the 14 samples that were positive by PCR only, culture grew no *S. aureus* but the patients had a recent history of MRSA, which consisted of MRSA colonization or infection within the prior year. This provided revised performance characteristics when these 6 were considered true positives (Table 1).

Real-time PCR using the achromopeptidase lysate compared to culture yielded 47 swabs positive for MRSA by both methods, 317 negative by both methods, 1 positive by culture only, 16 positive by PCR only, and 22 unresolved (5.5%) by PCR. Unresolved results were obtained initially for 47 samples (11.7%) and PCR reactions were repeated using the frozen lysate. On repeat PCR, 1 sample was positive (culture grew MRSA), 24 samples were negative, and 22 remained unresolved, of which 2 had MRSA identified in culture. The sensitivity, specificity, positive and negative predictive values are shown in Table 1. For 8 of the 16 samples that were positive by PCR only, culture grew no *S. aureus* but the patients had a recent history of MRSA that gave revised performance characteristics when these 8 were considered true positives (Table 1).

With both lysis methods the same 4 samples were called MRSA by PCR and methicillin-susceptible *S. aureus* (MSSA) by culture. Three of the four had isolates available for additional testing and all three were confirmed to be colony BD GeneOhm™ MRSA PCR positive and *mecA* PCR negative, representing definitive false-positive PCR results.

**High volume clinical use investigation using the in-house achromopeptidase lysis method.**

**PCR negative specimens.** Between November 2005 and December 2005 and March 2006 to May 2006 a total of 1198 specimens were tested by the PCR assay, and of these, there
were 1107 negative samples cultured to confirm the absence of MRSA. From those specimens, culture recovered MRSA from only one sample, which gives a negative predictive value (NPV) of 99.9% (95% confidence interval [95% CI] = 99.4-100%).

**PCR positive specimens.** During May 2006 and November 2006 a combined total of 3903 nasal specimens were tested by the PCR assay, and of these the 215 PCR positive samples were cultured for a thorough investigation to confirm the presence of MRSA. Since results for the investigation at the two time periods did not differ, the data was combined for this report. A total of 119 samples grew MRSA on the CNA plate, 15 samples had MRSA recovered from the TSB with 6.5% NaCl broth only, 32 samples grew MSSA on the CNA plate or in broth, and 49 samples were negative for *S. aureus* on the CNA plate and in broth. Of the samples that grew MSSA in culture, the isolated colonies were tested in the PCR assay with 16 being PCR positive and 16 testing negative. There was one patient whose nasal specimen grew an MSSA isolate that was PCR negative but who had MRSA recovered from an abscess collected on the same day. For the culture negative samples, 31 were from patients who had received some anti-staphylococcal antibiotics within the prior month and 23 were from patients with a history of MRSA within the last year. Thus, from this analysis, there were 134 samples with culture confirmed MRSA and 24 samples from patients with an MRSA history, these combined yield 158 true positives which correspond to a positive predictive value (PPV) of 73.5% (95% CI = 67-79.2%) for the PCR assay.

Calculating the sensitivity of culture for detecting patients harboring MRSA using this data set of 158 true positives found direct plating to be 75.3% sensitive (95% CI = 67.7-81.7%), whereas adding broth enrichment improved the sensitivity to 84.8% (95% CI = 78.0-89.8%). The sensitivity of the BD GeneOhm™ MRSA test for detecting a patient needing contact
isolation for MRSA was superior to either culture method ($p \leq 0.001$) and broth enrichment was superior to direct agar plating ($p \leq 0.05$) for detecting persons harboring MRSA.

**PCR unresolved specimens.** The unresolved rate was calculated for all tests performed during the first year of the universal surveillance program using the PCR assay with the achromopeptidase method. During clinical use there were 35,935 tests performed with the initial unresolved rate being 2.6%, which fell to 0.53% after retesting the refrigerated specimen lysates on the last run of each day.

**DISCUSSION**

There have been many reports dealing with the risks of MRSA colonization and infection and the benefits of active surveillance (9, 10), and are part of the new CDC guideline for management of multidrug-resistant organisms (4). The “search and destroy” method used in The Netherlands has allowed that country to maintain an MRSA prevalence in staphylococcal infections of <1% (27). Their program is multifaceted and one aspect includes presumptive isolation until active surveillance culture results are negative for MRSA colonization (2). The theoretical benefits of using a real-time PCR method instead of culture are rapid turnaround of results, suggesting the ability to wait a few hours for MRSA colonization status and then only isolate MRSA positive patients, and the capacity to increase the sensitivity of detection (18, 20). These have recently been shown to be significantly beneficial by Cunningham and colleagues who demonstrated a reduction in MRSA transmission incidence from 13.9/1,000 patient days using phenotypic (culture-based) MRSA surveillance to 4.9/1,000 patient days with PCR screening (4). Our study has shown that the BD GeneOhm™ MRSA real-time PCR assay, using the lysis method modification described here, is a sensitive and specific approach to achieve these benefits that is efficient to deploy in a setting of high-volume use.
Dealing with nasal specimens and using a real-time PCR assay avails itself to procedural optimization in sample preparation that permits high-volume testing. An alternative sample lysis method was designed and compared to the available kit method and the difference in hands-on time, ease of use and cost was clearly evident (Table 2), an aspect critical to implementation in most clinical laboratories. When both lysis methods showed the equivalent sensitivities and specificities (Table 1), the easier achromopeptidase method was selected to be used in our universal surveillance program where it has remained robust in over 1 year of use. Table 2 shows the difference in time to perform either lysis method when 14 samples, the maximum number for one SmartCycler instrument, are processed. What it does not fully demonstrate is the extra time effect and labor cost for a larger number of samples. The total time saved by using the achromopeptidase method when processing 14 samples is 12 minutes, but that increases to 17 minutes for 28 samples and over 2 hours for 98 samples, with the majority of the difference in hands-on labor. Our optimization permits one technologist to perform 120 to 150 tests in a single 8-hour shift and only adds $0.36 to the cost per test for the extra supplies. In addition to our alternate lysis method, there is another recently FDA-cleared assay for MRSA nasal surveillance that simplifies specimen preparation, the Xpert™ MRSA test (Cepheid, Inc.) that increases the options for surveillance programs.

Of interest was that during the initial validation the rate at which we obtained an unresolved result (indicating inhibition of the PCR reaction) was 11.7% with the achromopeptidase lysis. After repeating the PCR reaction with the same lysate the unresolved rate was 5.5%, which is consistent with the product insert. However, during the first month of all-admission surveillance the mean unresolved rate was 4.5% and after 7 months decreased to 3.5%. While the remainder of the first year demonstrated a 1.7% unresolved rate with 80% of
unresolved samples yielding a valid result upon repeat. There were no major changes to the lysis procedure that would account for the decrease in unresolved results. Possible explanations are that the technologists performing the test were slower in the beginning and with increased experience were able to start the PCR set-up and have the reactions in the instrument in a shorter period of time or the introduction of the updated PCR reagents. During the past 12 months our unresolved rate (after one repeat of initial unresolved tests) has remained under 1%. Others experiences with the BD GeneOhm™ MRSA assay using the kit lysis method published rates of 4.7% and 6.4% suggesting an improvement with the achromopeptidase method (16, 17). In daily testing, a specimen with an unresolved result has the PCR reaction repeated once. If it remains unresolved, the specimen is plated and culture is used to determine the presence of MRSA.

Our PCR validation included a thorough investigation for MRSA on discordant results. If the PCR results or culture did not agree, the PCR reaction was repeated and a broth-enrichment was added to the culture. Even after broth-enrichment, there were still cases of samples being PCR positive and culture negative. These samples can be calculated as false positive PCR results or potentially false negative cultures. In the case of PCR positive with MSSA in culture, testing the colonies by PCR identified 3 samples in the initial investigation and 16 during the high-volume use that were PCR positive. These most likely represent the previously described staphylococcal cassette chromosome mec (SCCmec) remnant (7, 11). The SCCmec contains the mecA gene and is a mobile element, the right insertion junction of this cassette into the S. aureus chromosome is the target of the PCR assay. In some cases, S. aureus have a partial excision of the SCCmec and no longer have the mecA gene but still have some of the junction section. These MSSA are misidentified as MRSA and are true false PCR positives. In the case of PCR positive and culture negative by no growth of any S. aureus or grew MSSA
colonies that are not PCR positive, additional information is necessary to assess their classification. Therefore, patients with these results had their medical record examined to determine if they had a history of MRSA colonization or infection. The majority of people colonized with MRSA remain colonized for years (24), so we believe that previous specimens positive for MRSA are good evidence that these patients carry this pathogen and a positive molecular test for MRSA in their nose represents a valid result for a MRSA surveillance program. Since nasal colonization with \textit{S. aureus} serves as a source for the organism to spread to other parts of the body and antedates bacteremia as well as non-bacteremic infection (12, 28), it is most likely that these patients truly harbored the microbe, even if it was not cultivatable in the nares at the time of our sampling, perhaps another benefit of molecular testing over traditional culture techniques.

Albeit the recognized ecologic niche of \textit{S. aureus} is the anterior nares (30), there is a question of whether to sample other body sites such as groin, axilla, or skin in addition to the nose or is the nose alone sufficient for MRSA surveillance. There would be an increased effort and cost associated with testing multiple sites. Studies have shown the sensitivity for detection of MRSA is 90\% for nose only specimens and 88\% for nose and groin combined and 76.5\% for skin or other superficial sites (1, 6) suggesting that nose alone is an adequate sample. Our own data indicated nasal surveillance captured >90\% of MRSA colonization (25), and thus we adopted nasal surveillance as our plan for MRSA control.

Since any MRSA surveillance program has the objective to detect the most persons harboring MRSA the goal is to have a sensitive test that detects MRSA carriage with a high NPV. Our results indicating the suboptimal performance of conventional testing compared to real-time PCR, particularly without prior broth enrichment before plating to agar, are supported
by the recent publication by Nahimana and colleagues who found a sensitivity of 47-65% with
direct plating to four chromogenic media products compared to 79-95% when prior broth
enrichment was included (9). This report did not include PCR testing and our data further
suggests that agar based surveillance remains less sensitive than molecular amplification even
when broth enrichment is included. More recently, using PCR as a comparison, Wren and
colleagues also found this with direct plating to agar only having a sensitivity of 62%, which
increased to 85% when broth enrichment before plating was employed (31)

Limitations of our report are that the testing for PPV and NPV during high-volume
clinical use was not done simultaneously but rather sequentially. However, the fact that we have
included a very large number of samples in our testing assessment and that performance has
remained constant during a period of more than 17 months suggests that the results presented are
reliable.

Using the achromopeptidase lysis method with the BD GeneOhm™ MRSA real-time
PCR assay, a universal surveillance program to screen all-admissions for MRSA was possible in
a healthcare organization with more than 40,000 annual admissions, which translates to over 100
specimens per day. The performance of the PCR assay was evaluated during this high-volume
testing to confirm its reliability and we found the assay performed at least as well as in our
original evaluation. Our results with the BD GeneOhm™ MRSA assay show it is an accurate
and rapid way to detect MRSA colonization. When dealing with large specimen numbers, the
achromopeptidase lysis method offers easier processing than the kit-recommended method
without negatively affecting PCR sensitivity or specificity.
ACKNOWLEDGMENTS

The BD GeneOhm™ MRSA kits for the initial investigation were a gift from GeneOhm Sciences. We thank the Evanston Northwestern Healthcare Microbiology Laboratory for their valuable contribution to the universal MRSA surveillance program.
REFERENCES


13. Nahimana, I., P. Francioli, and D. S. Blanc. 2006. Evaluation of three chromogenic media (MRSA-ID, MRSA-Select and CHROMagar MRSA) and ORSAB for surveillance


**TABLE 1.** Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of the BD GeneOhm™ MRSA real-time PCR using two different lysis methods compared to culture for initial comparison (original PCR formulation).

<table>
<thead>
<tr>
<th>Lysis Method</th>
<th>Sensitivity (95% CI)</th>
<th>Specificity (95% CI)</th>
<th>PPV (95% CI)</th>
<th>NPV (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kit lysisa (Prevalence = 12.3%)</td>
<td>98.0% (87.8-99.9%)</td>
<td>96.0% (93.2-97.7%)</td>
<td>77.4% (64.7-86.7%)</td>
<td>99.7% (98.1-100%)</td>
</tr>
<tr>
<td>Kit lysis with MRSA historyb (Prevalence = 14.2%)</td>
<td>98.2% (89.0-99.9%)</td>
<td>97.7% (95.3-98.9%)</td>
<td>87.1% (75.6-93.9%)</td>
<td>99.7% (98.1-100%)</td>
</tr>
<tr>
<td>Achromopeptidase lysisa (Prevalence = 12.6%)</td>
<td>97.9% (87.5-99.9%)</td>
<td>95.2% (92.2-97.1%)</td>
<td>74.6% (61.8-84.4%)</td>
<td>99.7% (98.0-100%)</td>
</tr>
<tr>
<td>Achromopeptidase lysis with MRSA historyb (Prevalence = 14.7%)</td>
<td>98.2% (89.2-99.9%)</td>
<td>97.5% (95.0-98.9%)</td>
<td>87.3% (76.0-94.0%)</td>
<td>99.7% (98.0-100%)</td>
</tr>
</tbody>
</table>

a True positive samples were samples that had MRSA isolated in culture.

b True positive samples were samples that had MRSA isolated in culture and samples from patients with a history of MRSA colonization or infection.
TABLE 2.

Comparison of time, ease of use and cost to process 14 samples.

<table>
<thead>
<tr>
<th></th>
<th>Kit lysis</th>
<th>Achromopeptidase lysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Break swab into tube:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>Reagents</td>
<td>Included</td>
<td>$5.04</td>
</tr>
<tr>
<td><strong>Hands-on time</strong></td>
<td><strong>22 min</strong></td>
<td><strong>3 min</strong></td>
</tr>
<tr>
<td><strong>Labor cost</strong></td>
<td><strong>$11.00</strong></td>
<td><strong>$1.50</strong></td>
</tr>
<tr>
<td>Incubation time</td>
<td>13 min</td>
<td>20 min</td>
</tr>
<tr>
<td><strong>Total time</strong></td>
<td>35 min</td>
<td>23 min</td>
</tr>
<tr>
<td>Set-up PCR reaction</td>
<td>Same</td>
<td>Same</td>
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