**Evaluation of Modified Hodge Test as a Non-molecular Assay for Accurate Detection of KPC-producing Klebsiella pneumoniae**

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**Abstract**

*Klebsiella pneumoniae* carbapenemase (KPC) have become a major therapeutic challenge because of its increasingly fast dissemination throughout the world. Accurate detection of KPC is essential for optimal treatment. The Clinical and Laboratory Standards Institutes (CLSI) for fast detection of KPC producers currently recommend Modified Hodge Test (MHT) and Carba NP test. MHT can directly detect carbapenemase production in *Enterobacteriaceae* isolates. The current study was conducted to evaluate the capacity of MHT with two carbapenem disks for accurate detection of KPC. MHT was performed according to guidelines of CLSI to identify isolates with carbapenem resistance. In doing so, two substrates of MHT were assigned into two groups for examination: meropenem and ertapenem groups. A total of 96 non-repetitive clinical isolates of *Klebsiella pneumoniae* were tested. The presence of the *bla*KPC gene in each MHT-positive isolate was examined by PCR. A total of 54 isolates exhibited reduced susceptibility or resistance to carbapenems. Specificity of the MHT with meropenem disk was 64% and with ertapenem disk was 53%. Detection of KPC by MHT with meropenem disk was found to be more effective than with ertapenem disk. Based on our results, the presence of KPC does not in itself influence the categorization of resistance. Therefore, the use of MHT with ertapenem disk for the rapid detection of KPC among *K. pneumoniae* for infection control should not be recommended.

**Keywords:** *Klebsiella pneumoniae*, carbapenem disks, detection method, Modified Hodge Test, KPC

**Introduction**

*Klebsiella pneumoniae* causes serious hospital-acquired infections of the urinary tract, respiratory tract, surgical sites, and the bloodstream and can cause severe diseases, such as pneumonia, sepsis, and bacteremia (Maroncle et al. 2002; Paterson 2006). The resistance of *K. pneumoniae* has significantly increased with the rampant use of beta-lactam antibiotics, such as carbapenems. Carbapenems are often the last treatment option for infections caused by these multidrug-resistant bacteria. Therefore, the major concern is the development of resistance against carbapenems (Nordmann et al. 2011; Barwa and Shaaban 2017).

*Klebsiella pneumoniae* carbapenemase (KPC) is a class-A β-lactamase, and the most active family of carbapenemases. The development of antibiotic resistance by class-A Ambler enzymes, such as KPC, generally leads to increased cessation in the treatment of infections (Hashemi et al. 2014; Bachman et al. 2015; Barwa and Shaaban 2017). The strains possessing the *bla*KPC gene have spread worldwide; this has resulted in increased concern for healthcare services worldwide (Woodford et al. 2010). Detection of carbapenemases in *Enterobacteriaceae* is essential to control the development of resistance in this family, particularly in *K. pneumoniae* isolates. The identification of *K. pneumoniae* isolates producing KPC has become a major concern for clinicians (Djahmi et al. 2014).

In recent years, various phenotypic confirmatory tests to detect the presence of carbapenemase enzymes in *Enterobacteriaceae* have been evaluated by testing the growth of such organisms in CHROMagar KPC medium, Chrom ID ESBL medium, Supercarba
medium and other tests, i.e., Neo sensitabs (Samra et al. 2008; Nordmann et al. 2011; Aliskan et al. 2012; Hansen et al. 2012).

CLSI has recommended the use of MHT and Carba NP tests for carbapenemase detection in Enterobacteriaceae. Because of variations in sensitivity and specificity for detection of KPC producers, the identification of such bacteria through these tests is difficult (Vasoo et al. 2013; Shinde et al. 2017). MHT has acceptable sensitivity. It is easy to perform, inexpensive and feasible for practically all-clinical laboratories; however, it lacks specificity (Anderson et al. 2007; Pasteran et al. 2009; Pasteran et al. 2010). MHT was suggested for detection of carbapenemase-producers based on their in vivo production of carbapenemases (Galani et al. 2008; Centers for Disease and Prevention 2009; Miriaigou et al. 2010).

The purpose of this study was to evaluate the effectiveness of MHT as a phenotypic confirmatory test with 2 different substrates for KPC screening. Additionally, PCR was performed for the detection of blaKPC gene.

Experimental

Materials and Methods

Bacterial collection and Ribotyping analysis. K. pneumoniae isolates were collected from 96 consecutive hospital inpatients and/or outpatients admitted to the AL Zahra hospital in Esfahan, Iran between February and June 2016.

PCR amplification was used for PCR-ribotyping based on internal transcribed spacer (ITS). The procedure implemented was as follows. Template DNA for the PCR was prepared from overnight culture of K. pneumoniae on nutrient agar (Scharlo, Spain). Five colonies from the overnight culture on TSA medium (Scharlo, Spain) were suspended in 100 µl distilled water. The boiling lysis method was used for DNA extraction. Cell debris was centrifuged at 13684 RCF for three minutes. Supernatants were used as the source of template DNA for amplification. Strain identifications were performed by analysis of the ITS. PCR-ribotyping was performed using PCR Master Mix 2X (Thermo Scientific, Germany) and specific primers (Liu et al. 2008).

Antimicrobial susceptibility testing. The disk diffusion methods using meropenem, ertapenem disks (Rosco, Denmark) were conducted on the basis of CLSI recommendations. Escherichia coli ATCC 25922 and K. pneumoniae 700603 were used as reference strains for susceptibility testing (CLSI).

Phenotypic confirmation test. In our study all isolates were subjected to MHT, according to the following procedure. Ertapenem disks (10 µg) (Rosco, Denmark), and meropenem disks (10 µg) (Rosco, Denmark) were used for MHT. The MHT indicator organism, E. coli ATCC 25922, was suspended in Mueller-Hinton broth (Scharlo, Spain) to obtain a suspension with turbidity of a 0.5 McFarland standard. The suspension was diluted 1:10 and plated on Mueller-Hinton agar (Scharlo, Spain). The carbapenem disk was placed in the centre of plates, and the isolates were streaked from the margin to the central disk by sterile swab. Two isolates were tested per plate. The plates were then incubated at 35°C for 18–20 hours. The production of a clover leaf-like indentation of the E. coli ATCC 25922 growth indicated a positive result for MHT (CLSI).

Genotypic confirmation test. All isolates were subjected to PCR to check for the presence of the blaKPC gene. K. pneumoniae ATCC BAA-1705 and K. pneumoniae ATCC BAA 1706 were used as quality control strains. A commercial DNA plasmid extraction kit was used (IBRC, Iran) to purify and characterize the plasmid DNA derived from the isolates. The primers used for amplification of blaKPC gene were designed in this study. The forward and reverse primers were

![Fig. 1. Result of antimicrobial susceptibility of positive MHT isolates by ertapenem disk. Antimicrobial susceptibility of ertapenem disk and its patterns compared with existence of the blaKPC gene. Results show that 25% isolates were MHT-negative and resistant to ertapenem disk.](image)
KPC-F: ATGTCACTGTATCGCCGTCT, and KPC-R: GCTGTGCTTGTCATCCTTGT (Fazabitech, Iran), respectively. The primers were used at 1 µmol concentration. The amplification product was expected to be 819 bp in length.

PCR reactions were performed using a thermocycler with the following conditions: initial denaturing at 95°C for 5 min, followed by 35 cycles of 60 sec of denaturation at 95°C, annealing at 53°C for 30 sec, elongation at 72°C for 90 sec, and a final extension at 72°C for 10 min.

Results

Bacterial isolation. A total of 96 K. pneumoniae were isolated from 96 different patients of whom 15.6% were outpatient and 84.4% were admitted to internal medicine wards. Clinical specimens included 30 urine, 16 wound swabs, one peritoneal-fluid, 6 blood samples, 34 respiratory secretions, and 9 other specimens.

Positive MHT patterns. 37 isolates were classified as carbapenem-resistant using MHT with the meropenem disk, and 47 with the ertapenem disk. A total of 54 isolates (some isolates showed positive result with the use of both disks) were classified as carbapenemase-producer.

Antimicrobial susceptibility patterns. The antimicrobial susceptibility test for two carbapenem antibiotics revealed that 49 isolates (51.04%) were resistant to ertapenem, and 60 isolates (62.5%) were resistant to meropenem.

Antimicrobial susceptibility patterns based on MHT results. 25 percent of the isolates were resistant to ertapenem, whereas they showed negative results by MHT with ertapenem disk (Table I). Only 29 (30.2%) of the 32.9% MHT-positive isolates with meropenem disk were resistant to meropenem (Table II).

Molecular analysis of bla\textsubscript{KPC} gene. Five of the 54 isolates, which were carbapenem-resistant and possessed the bla\textsubscript{KPC} gene, were detected using PCR. Three of these 5 isolates exhibited MHT-positive phenotype with both disks, one with meropenem disk, and one with ertapenem.

Antimicrobial susceptibility of bla\textsubscript{KPC} gene. The disk diffusion method was interpreted for KPC-producing K. pneumoniae isolates as follows: four isolates (4.17%) were resistant to carbapenem disks, two isolates were sensitive to ertapenem disk, and one isolate (1.04%) was intermediate to meropenem disk.

### Table I

<table>
<thead>
<tr>
<th>MHT</th>
<th>Sensitive</th>
<th>Intermediate</th>
<th>Resistant</th>
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<tbody>
<tr>
<td>Negative</td>
<td>22.9%</td>
<td>3.1%</td>
<td>25.0%</td>
</tr>
<tr>
<td>Positive</td>
<td>14.6%</td>
<td>8.3%</td>
<td>26.0%</td>
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*Table I: Result of antimicrobial susceptibility pattern*\textsuperscript{a} of MHT\textsuperscript{b} by ertapenem disk.

\textsuperscript{a} The interpretation was performed based in CLSI guideline (M100-S25). Antimicrobial susceptibility tests were determined using disk diffusion methodology.

\textsuperscript{b} MHT positive and negative results were interpreted using the CLSI guideline (M100-S25).

### Table II

<table>
<thead>
<tr>
<th>MHT</th>
<th>Sensitive</th>
<th>Intermediate</th>
<th>Resistant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative</td>
<td>15.6%</td>
<td>13.5%</td>
<td>32.3%</td>
</tr>
<tr>
<td>Positive</td>
<td>5.2%</td>
<td>3.1%</td>
<td>30.2%</td>
</tr>
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</table>

*Table II: Result of antimicrobial susceptibility pattern*\textsuperscript{a} of MHT\textsuperscript{b} by meropenem disk.

\textsuperscript{a} The interpretation was performed based in CLSI guideline (M100-S25). Antimicrobial susceptibility tests were determined using disk diffusion methodology.

\textsuperscript{b} MHT positive and negative results were interpreted using the CLSI guideline (M100-S25).
Discussion

The rapid detection of carbapenemase-producing strains in clinical samples is critically important to provide appropriate treatment. As a phenotypic test, MHT is widely used for first-line detection of carbapenem resistance in clinical laboratories (Carvalhaes et al. 2010; Cury et al. 2012; Chande et al. 2013). In the current study, we evaluated the efficiency of MHT test with two different carbapenem disks as substrate for identification of KPC enzyme and compared it using PCR.

In this examination, 54 K. pneumoniae isolates were MHT-positive, while only five of them were carriers of blaKPC gene. Our finding seems to be consistent with those other studies that obtained false-positive results for MHT. Therefore, the use of MHT alone should not be recommended to confirm the presence of carbapenemase produced by Enterobacteriaceae (Bayramoglu et al. 2016).

Varying sensitivity and specificity of MHT were found in different studies (Doyle et al. 2012; Lari et al. 2014; Shinde et al. 2017; Sun et al. 2017). One study revealed that MHT with ertapenem disk could be utilized for the detection of carbapenemases in isolates that showed intermediate or sensitive zone diameter on disk diffusion (Amjad et al. 2011). Another study demonstrated that the MHT with ertapenem disk had predictive significance of KPC detection in Enterobacteriaceae (Cury et al. 2012).

Our results revealed that the sensitivity of MHT test with meropenem and ertapenem disks was equal (80%). Hence, using two carbapenem disks as substrate for MHT led to excellent sensitivity for the detecting of KPC producers. The specificity of MHT with ertapenem and meropenem disks was found to be low: 53% and 64%, respectively. However, the specificity of ertapenem disk was much lower than the meropenem disk.

MHT cannot be considered as a good indicator for the detection of KPC producers because of its low specificity. The meropenem disk was more effective than ertapenem disk as a substrate for MHT. Nevertheless, MHT results alone are not sufficient to predict carbapenem resistance. One limitation of the study is that we did not detect other carbapenemase producers. MHT showed carbapenemase activity other than carbapenemase production. The resistance could be related to some other mechanisms. PCR yielded sufficient results for detection of KPC-producing isolates. We recommended that improvement in MHT for the screening of KPC producers with high specificity is required for accurate detection.

Acknowledgements

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Ethical approval

The study was approved by the Ethics Committee of the Alzahra Hospital (Letter number A/120). All microbiological samples were taken as part of standards care procedures. No written informed consent was necessary for this type of study.

Literature


CLSI CaLSI. 2016. Performance standards for antimicrobial susceptibility testing; twenty-sixth informational supplement. Wayne, PA.


