MULTIPLEXED POLYMERASE CHAIN REACTION FOR GENETIC SEQUENCE ANALYSIS

This application claims priority to US Provisional Patent Application Nos. 60/691,768, filed on 16 Jun 2005; 60/735,876 filed on 14 Nov 2005; 60/735,824 filed on 14 Nov 2005; and 60/743,639, filed on 22 Mar 2006, and to US Patent Application Nos. 11/422,425, filed on 06 Jun 2006 and 11/422,431, filed on 06 Jun 2006. This application is a continuation-in-part application of US Patent Application Nos. 11/177,647, filed 02 Jul 2005; 11/177,646, filed 02 Jul 2005; and 11/268,373, filed on 07 Nov 2005. These nonprovisional applications claim priority to US Provisional Patent Application Nos. 60/590,931, filed on 02 Jul 2004; 60/609,918, filed on 15 Sep 2004; 60/626,500, filed on 05 Nov 2004; 60/631,437, filed on 29 Nov 2004; and 60/631,460, filed on 29 Nov 2004.

TECHNICAL FIELD

The invention relates generally to amplification methods of multiple genetic targets and analysis of amplified products using microarrays.

BACKGROUND ART

Accurate and rapid identification of infectious pathogens causing acute respiratory infections (ARI) in humans can be a critical factor in the successful treatment of respiratory illness, the application of appropriate outbreak control measures, and the efficient use of precious antibiotics and antiviral drugs. However, clinical differential diagnosis of ARI is challenging due to the similarity of the symptoms caused by different pathogens and the number and biological diversity of those agents. Currently, the most widely used methods for respiratory pathogen identification are culture, immunoassay, and RT-PCR/PCR assays. Culture and immunoassay techniques are generally specific to a particular pathogen, and as such are limited to detecting a single suspected agent at the species and sometimes serotype levels. In contrast, nucleic acid based techniques such as RT-PCR/PCR are versatile, offering high sensitivity in the detection of all pathogens, including fastidious or otherwise difficult-to-culture organisms. Because of the versatile nature of PCR, the technique can be applied simultaneously to multiple agents, increasing the chances of establishing specific etiology (McDonough et al., "A multiplex PCR for detection of Mycoplasma pneumoniae, Chlamydophila pneumoniae, Legionella pneumophila, and Bordetella pertussis in clinical specimens" *Mol. Cell Probes*, **19**, 314-322 (2005)) and allowing accurate detection of simultaneous infections involving more than one pathogen (Grondahl et al., "Rapid identification of nine microorganisms causing acute respiratory tract infections by single-tube multiplex reverse transcription-PCR: feasibility study" *J. Clin. Microbiol.*, **37**, 1-7 (1999)).

Detection of several organisms within one reaction by multiplex approaches is desirable since ARI agents can be symptomologically nonspecific. Thus, assaying for one pathogen at a time is inefficient and does not produce information regarding possible co-infections. Several multiplex RT-PCR/PCR tests have been developed to address this (McDonough; Grondahl; Puppe et al., "Evaluation of a multiplex reverse transcriptase PCR ELISA for the detection of nine respiratory tract pathogens" *J. Clin. Virol.*, **30**, 165-174 (2004); Bellau-Pujol et al., "Development of three multiplex RT-PCR assays for the detection of 12 respiratory RNA viruses" *J. Virol. Methods*, **126**, 53-63 (2005); Miyashita et al., "Multiplex PCR for the simultaneous detection of Chlamydia pneumoniae, Mycoplasma pneumoniae and Legionella pneumophila in community-acquired pneumonia" *Respir. Med.*, **98**, 542-550 (2004); Osiowy, "Direct detection of respiratory syncytial virus, parainfluenza virus, and adenovirus in clinical respiratory specimens by a multiplex reverse transcription-PCR assay" *J. Clin. Microbiol.*, **36**, 3149-3154 (1998); Verstrepen et

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al., "Rapid detection of enterovirus RNA in cerebrospinal fluid specimens with a novel single-tube real-time reverse transcription-PCR assay" *J. Clin. Microbiol.*, **39**, 4093-4096 (2001); Coiras et al., "Simultaneous detection of fourteen respiratory viruses in clinical specimens by two multiplex reverse transcription nested-PCR assays" *J. Med. Virol.*, **72**, 484-495 (2004); Coiras et al., "Oligonucleotide array for simultaneous detection of respiratory viruses using a reverse-line blot hybridization assay" *J. Med. Virol.*, **76**, 256-264 (2005); Gruteke et al., "Practical implementation of a multiplex PCR for acute respiratory tract infections in children" *J. Clin. Microbiol.*, **42**, 5596-5603 (2004)) but the approach is limited by the discriminating power of current amplicon detection methods. Gel-based analysis approaches tend to be restricted to a limited number of pathogens whose products can be discriminated by size alone while fluorescent reporter systems like real-time PCR are limited by the number of the fluorescent peaks that can be unequivocally resolved – no more than three or four. Thus, there is a need for diagnostic assays that allow rapid differentiation and identification of the pathogens responsible for disease syndromes with many potential causes, such as ARI.

A few technologies have been developed that allow more pathogens to be detected simultaneously by RT-PCR/PCR methods. Multiplex identification of up to 22 respiratory pathogens has been achieved by the MASSCODE™ multiplex RT-PCR system (Briese et al., "Diagnostic system for rapid and sensitive differential detection of pathogens" *Emerg. Infect. Dis.*, **11**, 310-313 (2005)). Spotted (especially long-oligonucleotide) microarrays have also been used with some success as a multiplex PCR analysis tool (Roth et al., "Use of an oligonucleotide array for laboratory diagnosis of bacteria responsible for acute upper respiratory infections" *J. Clin. Microbiol.*, **42**, 4268-4274 (2004); Chizhikov et al., "Microarray analysis of microbial virulence factors" *Appl. Environ. Microbiol.*, **67**, 3258-3263 (2001); Chizhikov et al., "Detection and genotyping of human group A rotaviruses by oligonucleotide microarray hybridization" *J. Clin. Microbiol.*, **40**, 2398-2407 (2002); Wang et al., "Microarray-based detection and genotyping of viral pathogens" *Proc. Natl. Acad. Sci. USA*, **99**, 15687-15692 (2002); Wang et al., "Viral discovery and sequence recovery using DNA microarrays" *PLoS Biol.*, **1**, E2 (2003); Wilson et al., "High-density microarray of small-subunit ribosomal DNA probes" *Appl. Environ. Microbiol.*, **68**, 2535-2541 (2002); Wilson et al., "Sequence-specific identification of 18 pathogenic microorganisms using microarray technology" *Mol. Cell. Probes*, **16**, 119-127 (2002); Call et al., "Identifying antimicrobial resistance genes with DNA microarrays" *Antimicrob. Agents Chemother.*, **47**, 3290-3295 (2003); Call et al., "Mixed-genome microarrays reveal multiple serotype and lineage-specific differences among strains of Listeria monocytogenes" *J. Clin. Microbiol.*, **41**, 632-639 (2003). The primary limitation of these systems is the inability to discriminate closely related strains of the same organism because the detected hybridization events may be insensitive to partial sequence divergence. For instance, spotted microarray probes may cross-hybridize nonspecifically with sequences that vary by as much as 25% – an unfortunate event considering the fact that this invisible variation carries enough information to allow a high degree of strain differentiation if the polymorphisms could be specifically defined.

Strain-level identification can be critical in cases where closely related organisms can have very different clinical consequences and epidemiological patterns. In such cases, strains must be discriminated to allow proper treatment and control. The clinically relevant *Bordetella pertussis* and its sister species, the clinically irrelevant *B. parapertussis,* offer a classic example. Another example is influenza viruses, for which discrimination of vaccine-sensitive and -insensitive strains, as well as circulating human isolates and possible zoonotic strains (*e.g.* avian H5N1) is of immediate and obvious value.

DISCLOSURE OF THE INVENTION

The invention comprises a method comprising: providing a biological sample suspected of containing one or more pathogen nucleic acids from a predefined set of pathogens; adding to the sample a plurality of PCR primers corresponding to genes found in the predefined set of pathogens; and performing a polymerase chain reaction on the sample to amplify a subset of the nucleic acids that correspond to the genes. The primers include at least one primer pair for each pathogen, and the primers comprise a tail sequence that is not homologous any pathogen DNA or to any background DNA in the sample. The concentration of at least one primer in the polymerase chain reaction is no more than about 100 nM.

MODES FOR CARRYING OUT THE INVENTION

In the following description, for purposes of explanation and not limitation, specific details are set forth in order to provide a thorough understanding of the present invention. However, it will be apparent to one skilled in the art that the present invention may be practiced in other embodiments that depart from these specific details. In other instances, detailed descriptions of well-known methods and devices are omitted so as to not obscure the description of the present invention with unnecessary detail.

Clinical syndromes are seldom specific to single pathogens, so assays that allow testing for, and discriminating among, a large number of candidate pathogens will undoubtedly be beneficial to public health efforts. The work presented here demonstrates the clinical diagnostic and epidemiological surveillance potentials of a resequencing array (RA) approach that combines multiplex RT-PCR/PCR, RA, and automated sequence similarity searching and pathogen identification – the RPM v.1 system, for 20 common respiratory pathogens, as well as 6 biothreat agents under a broad spectrum of conditions. By combining the sensitivity of multiplex PCR amplification with the specificity of a RA, the trade-off between specificity and sensitivity that is often seen when evaluating diagnostic assays may be averted. This was demonstrated using control samples whether in extraction buffer or together as complex mixtures spiked into healthy patient clinical samples. The data also shows that the system offers equivalent sensitivity to accepted RT-PCR/PCR- and culture-based methods for both HAdV and influenza A virus, using 101 throat-swab samples from patients with influenza-like illness.

Short-oligonucleotide resequencing arrays (RA) may simultaneously provide both species-level and strain-level identification of PCR amplicons from ARI pathogens. Strain-specific information, including unique polymorphisms from previously unrecognized variants, is provided by the RA's ability to reveal sequence differences that distinguish the hybridized target from the prototype sequences (ProSeqs, see US Patent Application No. 11/___,___ to Malanoski et al., entitled "Computer-Implemented Biological Sequence Identifier System and Method", and filed on the same day as the present application) tiled on the array. Prior studies combined a custom designed Respiratory Pathogen Microarray (RPM v.1) with methods for microbial nucleic acid enrichment, random nucleic acid amplification and automated sequence similarity searching to achieve broad-spectrum respiratory tract pathogen identification at both species and strain levels with unambiguous statistical interpretation (Lin et al., "Broad-spectrum respiratory tract pathogen identification using resequencing DNA microarrays" *Genome Res.*, **16**(4), 527-535 (2006); Wang et al., "Rapid, Broad-spectrum Identification of Influenza Viruses by Resequencing Microarrays" *Emerg. Infect. Dis.*, **12**(4), 638-646 (2006)). However, generic amplification methods had limited success when dealing with clinical samples that have lower titer of pathogens. Disclosed herein is an improved multiplex PCR amplification strategy that mitigates the sensitivity issue related to random target amplification. Successful proof-of-concept experiments, utilizing clinical samples obtained from patients presenting

ARI, demonstrate that high species-level concordance with standard reference assays (*e.g.* culture, College of American Pathologist [CAP]-certified PCR) can be achieved while still producing correct species and strain-level identification via direct sequence reads in an improved assay time (8.5 hours). The results suggest that this approach is amenable to a straightforward automation and miniaturization process and thus could lead to a microarray-based platform for both diagnostics and surveillance purposes.

The polymerase chain reaction (PCR) is well known in the art. The present method uses a biological sample that may contain pathogen nucleic acids. The method does not require the presence of the pathogen nucleic acids, as the method may be performed on, for a example, a specimen from a healthy individual. As a preliminary step, the pathogen nucleic acids may be extracted from a clinical sample such as, but not limited to, a nasal wash, a throat swab, sputum, blood, or an an environmental sample. The clinical sample may be obtained from an organism of any species including, but are not limited to, humans. Any type of pathogen may be tested for including, but not limited to, respiratory pathogens, enteric pathogens, and biothreat agents such as anthrax spores. The set of pathogens may be defined at, for example, the species level or the strain level.

The method involves PCR primers that correspond to genes that may be found in the pathogens. PCR primers are well known in the art. There is at least one primer pair for each pathogen. The primers used in the method have a tail sequence that is not homologous to the DNA of any of the pathogens or to any background DNA in the sample. The background DNA may be the DNA of the species from which a clinical sample was obtained. Potential tail sequences may be randomly or otherwise generated and may be evaluated by, for example, comparison to a database of genetic sequences, such as GenBank. The tail sequence generally does not itself bind to the pathogen DNA and may reduce the formation of primer-dimers in the PCR, as the tail is not complementary to any other primer. Suitable tails for use with a specimen obtained from humans include, but are not limited to, CGATACGACGGGCGTACTAGCG (Primer L, SEQ ID NO.1) and CGATACGACGGGCGTACTAGCGNNNNNNNNN (Primer LN, SEQ ID NO.2).

The set of primers in single PCR may include, for example, at least 30, 40, 50, 60, 70, 80, 90, or 100 different primers. Primers corresponding to genes of varying lengths may be used in the same PCR. For example, amplified nucleic acids of lengths less than 50, 100, or 200 and more than 3000 or 2000 nucleotides may be produced in a single PCR.

A PCR using these primers may include other components or use equipment as generally known in the field of PCR and as disclosed herein. Low concentrations of primers may be used in the reaction. From one to all of the primers may be present at a concentration of no more than about 100 nM. Lower concentrations such as 40-50 nM may be used.

The biological sample may be divided into a plurality of aliquots and a separate PCR using different primers performed on each aliquot. The aliquots may then be recombined after the PCR. This may be done when a large number of primers is used. The more primers that are used in a PCR, the more likely is the formation of primer-dimers. The PCR may be better optimized with multiple aliquots with different primer mixes.

After the PCR, an identification of the pathogen may be performed. This may be done by contacting the sample to a microarray comprising a plurality of nucleic acid sequences that are complementary to at least portions of the amplified nucleic acids, and allowing the amplified nucleic acids to hybridize to complementary nucleic acids. Such methods are described in US Patent Application No. 11/177,646. The complementary nucleic acids may be, but are not limited to, from 25- to 29-mers. The use of such short complementary nucleic acids reduces the possibility that any mismatches will hybridize to the microarray. The complementary nucleic acids may include a

perfect match probe to at least one of and up to all of the amplified nucleic acids and three different single nucleotide polymorphisms of the center position of each perfect match probe. This arrangement allows for the entire sequence of the gene to be determined, which can allow for identification of the strain of the pathogen.

After hybridization, known methods, such as fluorescence, may be used to to detect which complementary nucleic acids have hybridized amplified nucleic acids. The pathogen may then be identified based on which amplified nucleic acids are detected. This may be done by a pattern recognition algorithm, where the pathogen is identified based on which genes are hybridized to the array. It may also be done based on sequencing of the hybridized genes, as described above.

Molecular diagnostic techniques enable rapid and sensitive identification of etiological agents. Current methods, such as PCR, RT-PCR, and spotted microarray etc., are vulnerable to misidentification due to false positive and false negative test results, and tend to suffer from a direct tradeoff between sensitivity and specificity. Samples consist of a large and diverse group of background organisms which may also contain regions of similarity to the target sequence used for diagnostic PCR amplification. The genetic complexity of non-target DNA (especially human DNA) may cause the amplification of a "false positive" product due to cross reactivity. In addition, viruses evolve through mutation and recombination events at a very fast rate, making particularly sensitive tests subject to a state of constant redesign or almost immediate obsolescence. Genetic variations are also clinically relevant, as they may correlate to antigenic variations which have potential implications for persistence of infection and the response to treatment and/or vaccination. To study genetic variation with current PCR methods, additional sequencing steps are always required. The RPM v.1 method not only detects infectious agents at the species and strain levels, but can also identify subtle genomic differences without further experiment. This approach is also shown to be an effective means for detecting up to 7 pathogens simultaneously with high sensitivity and specificity, and allow unambiguous and reproducible sequence-based strain identification for pathogens with appropriately selected prototype sequence on the microarray (ProSeqs). This may be useful for enhancing clinical management and epidemic outbreak responses by permitting accurate fingerprinting, antibiotic resistance profiling, genetic drift/shift analysis, forensics, and many other parameters of each pathogen. This capability may be invaluable for rapid detection of emerging diseases, such as avian H5N1 influenza virus, and biological terrorism events.

Having described the invention, the following examples are given to illustrate specific applications of the invention. These specific examples are not intended to limit the scope of the invention described in this application.

Example 1

RPM v.1 chip design – The RPM v.1 (Respiratory Pathogen Microarray) chip design, included 57 tiled regions allowing resequencing of 29.7 kb of sequences from 27 respiratory pathogens and biowarfare agents, and was described in detail in a previous study (Lin et al., "Broad-spectrum respiratory tract pathogen identification using resequencing DNA microarrays" *Genome Res.*, **16**(4), 527-535 (2006)). Briefly, RPM arrays consist of sequential 25-mer perfect match probes representing (and centered on) each base in a sequence chosen from the genome of the target organisms. Furthermore, for each perfect match probe, three mismatch probes representing the three possible single nucleotide polymorphisms (SNPs) of the center position were also tiled on the array. Thus hybridization to a series of perfect matches provides redundant presence/absence information, while hybridization to mismatched probes reveals strain-specific SNP data. On this chip, two pathogens, HAdV and influenza A were given more probe representation than others. These were selected based upon clinical relevance for the population of immediate interest (United States military recruit in training). For HAdV, partial sequences from the *E1A*, *hexon*,

and *fiber* genes containing diagnostic regions of serotypes 4, 5, and 7 were tiled for the detection of all ARI-associated HAdVs. Similarly, tiled regions for influenza A virus detection were comprised of partial sequences from the *hemagglutinin* (subtypes H1, H3, and H5), the *neuraminidase* (subtypes N1 and N2), and the *matrix* genes. In addition to 3 HAdVs and 3 influenza A viruses, the current RPM design permits discrimination of 15 other common respiratory pathogens, and 6 Centers for Disease Control and Prevention category A bio-terrorism pathogens (Table 1) known to cause ARI, *i.e.* "flu-like" symptoms at early stages of infection. All control and field strains used to test the sensitivity and specificity of RPM v.1 and their sources are listed in Table 1.

Table 1: Analytic sensitivity of microarray-based detection for prototype control strains.

Organism	Sample Type	Strain	Sample Source	Detection limit (genome copies)
HAdV-4[@]	DNA	RI-67	ATCC	100
HAdV-4 vaccine	DNA	CL68578	NHRC	100
HAdV-4FS_Navy	DNA		NRHC	100
HAdV-4FS_AirForce	DNA		AFIOH	100
HAdV-4FS_AirForce	Viral particles		ADL	100
HAdV-5	DNA	adenoid 75	ATCC	1000
HAdV-7	DNA	Gomen	ATCC	100
HAdV-7	Viral particles	Gomen	ATCC	N.D.
HAdV-7a vaccine	DNA	55142	NHRC	100
HAdV-7FS_Navy	DNA		NHRC	1000
B. anthracis	DNA	AMES	AFIP	10*
B. anthracis	Bacterial cells	STERNE	CRP	N.D.
B. pertussis	DNA		NHRC	100
C. pneumoniae	DNA		ABi	10*
Influenza A-H1N1	Viral particles	PR/8/34	ABi	100
Influenza A-H3N2	RNA		ADL	100
Influenza A-H5N1	RNA		AFIOH	10*
Influenza B	Viral particles	B/Lee/40	ABi	1000
F. tularensis	DNA	SCHU4	ATCC	1000
F. tularensis	Bacterial cells	SCHU4	CRP	N.D.
Human coronavirus	NA	229E	ATCC	1000
Human coronavirus	Viral particles	229E	ATCC	N.D.
Human coronavirus	NA	OC43	ATCC	1000
Human coronavirus	Viral particles	OC43	ATCC	N.D.
Rhinovirus 89	Viral particles	41467 Gallo	ATCC	1000
Lassa Virus[#]	plasmids		BlueHeron	1000
M. pneumoniae	DNA		AFIP	1000
M. pneumoniae	Bacterial cells		NHRC	N. D.
N. meningitidis	DNA	Murray	ATCC	100
Parainfluenza Virus 1	Viral particles	C-35	ATCC	1000
Parainfluenza Virus 3	Viral particles	C 243	ATCC	1000
RSV A	Viral particles	A-2	ATCC	1000
RSV B	Viral particles	B WV/14617/85	ATCC	100
S. pneumoniae	DNA		AFIP	100
S. pyogenes	DNA	Rosenbach	ATCC	1000
S. pyogenes	Bacterial cells		NHRC	N.D.
Variola Major Virus[#]	plasmids		BlueHeron	1000
Vaccinia	DNA	Lister	ABi	1000
Y. pestis	DNA	D27	AFIP	1000
Y. pestis	Bacterial cells	CO92	CRP	N.D.
Ebola Virus[#]	plasmids		BlueHeron	1000

Note: [@]: plaque purified; *: the lowest detection limit tested; [#]: target genes were constructed and cloned into

pUC119 by BlueHeron Biotechnology (Bothell, WA).

Example 2

Clinical samples – Archived throat swabs were collected from patients with ARI symptoms at various military recruit training centers, US/Mexico border sites, and on deployed naval ships from 1999-2005. These were immediately placed in 2 mL cryogenic vials containing 1.5 mL of viral transport medium (VTM), frozen and stored at or below -80°C to maintain the viral particles during transport. Samples were then shipped to the Naval Health Research Center (NHRC, San Diego, CA), thawed and aliquoted, and tested for HAdV and influenza using CAP-certified diagnostic RT-PCR/PCR and culture tests. Frozen aliquots were then submitted for microarray-based detection in a blinded fashion.

Example 3

Nucleic acid extraction – Nucleic acid was extracted from clinical samples using either the MASTERPURE™ DNA purification kit (Epicentre Technologies, Madison, WI), omitting RNase digestion, or the MagNA Pure Compact Nucleic Acid Isolation Kit I (Roche Applied Science, Indianapolis, IN) following the manufacturer's recommended protocols.

Example 4

Internal controls – Two *Arabidopsis thaliana* genes, corresponding to NAC1 and triosphosphate isomerase (TIM), were chosen as internal controls for reverse transcription (RT) and PCR reactions as they would be unlikely to occur naturally in clinical samples. Two plasmids, pSP64poly(A)-NAC1 and pSP64poly(A)-TIM, containing ~ 500 bp of the two genes were kindly provided by Dr. Norman H. Lee at The Institute for Genome Research (Rockville, MD). NAC1 was amplified by PCR with SP6 and M13R primers, and the PCR products were purified using QIAquick PCR Purification Kit (Qiagen, Valencia, CA). To generate RNA from pSP64poly(A)-TIM, the plasmids were linearized with *EcoRI* and in vitro transcribed from the SP6 promoter using the MEGASCRIPT® High Yield Transciption Kit (Ambion, Austin, TX). 60 fg each of NAC1 and TIM were used as internal controls for checking the amplification efficiency and the presence of inhibitors in the specimens.

Example 5

Primer design and Multiplex RT-PCR amplification – Dividing the primers into two independent reactions simplified primer design and optimization. Fine-tuning adjustments to both mixtures (swapping primers that amplified poorly for new ones) were carried out to ensure all target genes from the 26 targeted pathogens (West Nile Virus is included on the array but not in this amplification scheme) would amplify sufficiently to allow hybridization. The gene-specific primer pairs for all targets on the RPM v.1 chip (listed Tables 2(a) and 2(b)) were designed to ensure good amplification efficiency for multiplex PCR. All primers were designed to have a similar annealing temperature, and checked to ensure uniqueness using a full search of the GenBank database with the BLAST program for known sequences. All primers were checked for potential hybridization to other primers to reduce the potential of primer-dimer formation. In addition, we adapted a method developed by Shuber et al., "A simplified procedure for developing multiplex PCRs" *Genome Res.*, **5**, 488-493 (1995) and Brownie et al., "The elimination of primer-dimer accumulation in PCR" *Nucleic Acids Res.*, **25**, 3235-3241 (1997) to further suppress primer-dimer formation by adding a linker sequence of 22 bp (primer L) to the 5'-end of primers used in this study. Reverse transcription (RT) reactions were performed in 20 µl volumes containing 50 mM Tris-HCl (pH 8.3), 75 mM

KCl, 3 mM $MgCl_2$, 500 µM each of dATP, dCTP, dGTP, dTTP, 40 U of RNaseOUT™, 10 mM DTT, 2 µM primer LN, 200 U of Superscript III (Invitrogen Life Technologies, Carlsbad, CA), 60 fg each of two internal controls (NAC1 and TIM), and 5-8 µl of extracted clinical specimen or laboratory control. Reactions were carried out in a Peltier Thermal Cycler- PTC240 DNA Engine Tetrad 2 (MJ Research Inc., Reno, NV) using the manufacturer's recommended protocol.

Table 2(a): List of PCR primers in primer mix A used for multiplex PCR

Primer name	Sequence (5'→ 3')	SEQ ID NO.	**Organism** *gene*	Amplicon size
FluAHA1-F2	CGA TAC GAC GGG CGT ACT AGC GGC CAA CAA CTC AAC CGA CAC	3	**Influenza A** *hemaggultinin*	810 bp
FluAHA1-R2	CGA TAC GAC GGG CGT ACT AGC GAC ACT TCG CAT CAC ATT CAT CC	4		
FluAHA3-F6	CGA TAC GAC GGG CGT ACT AGC GAC TTC CCG GAA ATG ACA ACA	5	**Influenza A** *hemaggultinin*	873 bp
FluAHA3-R7	CGA TAC GAC GGG CGT ACT AGC GGG TTT GTC ATT GGG AAT GCT	6		
FluAHA5-F2	CGA TAC GAC GGG CGT ACT AGC GGC CAT TCC ACA ACA TAC ACC	7	**Influenza A** *hemaggultinin*	736 bp
FluAHA5-R2	CGA TAC GAC GGG CGT ACT AGC GAG CTA CCA TGA TTG CCA GTG	8		
FluANA1-F5	CGA TAC GAC GGG CGT ACT AGC GAC GTT GTT GCT GGA AAG GAC	9	**Influenza A** *neuraminidase*	1000 bp
FluANA1-R6	CGA TAC GAC GGG CGT ACT AGC GAA ACT TCC GCT GTA CCC TGA	10		
FluANA2-F6	CGA TAC GAC GGG CGT ACT AGC GGG AAA TAT GCC CCA AAC TAG C	11	**Influenza A** *neuraminidase*	1029 bp
FluANA2-R6	CGA TAC GAC GGG CGT ACT AGC GAT GCA GCT TTT GCC TTC AAC	12		
FluAMA-F4	CGA TAC GAC GGG CGT ACT AGC GTT CTA ACC GAG GTC GAA ACG	13	**Influenza A** *matrix*	891 bp
FluAMA-R5	CGA TAC GAC GGG CGT ACT AGC GCT CTG GCA CTC CTT CCG TAG	14		
FluBHA-F5	CGA TAC GAC GGG CGT ACT AGC GGG GAG GTC AAT GTG ACT GGT	15	**Influenza B** *hemaggultinin*	898 bp
FluBHA-R5	CGA TAC GAC GGG CGT ACT AGC GGG GCA ATT TCC TAT GGC TTT	16		
FluBNA-F4	CGA TAC GAC GGG CGT ACT AGC GGT GAA CCG TTC TGC AAC AAA	17	**Influenza B** *neuraminidase*	899 bp
FluBNA-R3	CGA TAC GAC GGG CGT ACT AGC GCC AAT CTT GGA TGC CAT TCT	18		
FluBMA-F2	CGA TAC GAC GGG CGT ACT AGC GCA TTG ACA GAA GAT GGA GAA GG	19	**Influenza B** *matrix*	411 bp
FluBMA-R2	CGA TAC GAC GGG CGT ACT AGC GAA GCA CAG AGC GTT CCT AG	20		
Ad5 hexon-F2	CGA TAC GAC GGG CGT ACT AGC GCT GTG GAC CGT GAG GAT ACT	21	**Adenovirus 5** *hexon*	1768 bp
Ad5 hexon-R2	CGA TAC GAC GGG CGT ACT AGC GTT GGC GGG TAT AGG GTA GAG C	22		
Ad5 fiber-F2	CGA TAC GAC GGG CGT ACT AGC GTT ATT CAG CAG CAC CTC CTT G	23	**Adenovirus 5** *fiber*	2046 bp
Ad5fiber-R2	CGA TAC GAC GGG CGT ACT AGC GGG TGG CAG GTT GAA TAC TAG	24		
Ad5 E1A-F3	CGA TAC GAC GGG CGT ACT AGC GGG CTG ATA ATC TTC CAC CTC C	25	**Adenovirus 5** *E1A*	808 bp

Ad5 E1A-R3	CGA TAC GAC GGG CGT ACT AGC GCT CTC ACG GCA ACT GGT TTA A	26		
Ad4 hexon-F3	CGA TAC GAC GGG CGT ACT AGC GGA CAG GAC GCT TCG GAG TAC	27	**Adenovirus 4** *hexon*	1334 bp
Ad4 hexon-R3	CGA TAC GAC GGG CGT ACT AGC GGG CAA CAT TGG CAT AGA GGA AG	28		
Ad4 fiber-F2	CGA TAC GAC GGG CGT ACT AGC GGG TGG AGT GAT GGC TTC G	29	**Adenovirus 4** *fiber*	1245 bp
Ad4 fiber-R2	CGA TAC GAC GGG CGT ACT AGC GAG TGC CAT CTA TGC TAT CTC C	30		
Ad4F E1A-F1	CGA TAC GAC GGG CGT ACT AGC GGC CGT GGA GTA AAT GGC TAA	31	**Adenovirus 4** *E1A*	1506 bp
Ad4F E1A-R1	CGA TAC GAC GGG CGT ACT AGC GAG TCT TCC AAG ACC GTC CAA	32		
Ad7 hexon-F2	CGA TAC GAC GGG CGT ACT AGC GAT GTG ACC ACC GAC CGT AG	33	**Adenovirus 7** *hexon*	2417 bp
Ad7 hexon-R2	CGA TAC GAC GGG CGT ACT AGC GGT TGC TGG AGA ACG GTA TG	34		
Ad7 fiber-F1	CGA TAC GAC GGG CGT ACT AGC GTC TAC CCC TAT GAA GAT GAA AGC	35	**Adenovirus 7** *fiber*	688 bp
Ad7fiber-R1	CGA TAC GAC GGG CGT ACT AGC GGG ATA GGC AGT TGT GCT GGG CAT	36		
Ad7 E1A-F2	CGA TAC GAC GGG CGT ACT AGC GTG AGT GCC AGC GAG AAG AG	37	**Adenovirus 7** *E1A*	786 bp
Ad7 E1A-R2	CGA TAC GAC GGG CGT ACT AGC GCA GGA GGT GAG GTA GTT GAA TC	38		
A tha TIM-F2	CGA TAC GAC GGG CGT ACT AGC GTC AAA TCC TCG TTG ACA GAC	39	**A. thaliana** *TIM*	503 bp
A tha TIM-R2	CGA TAC GAC GGG CGT ACT AGC GTG CAC TGT TGC CTC CAT TGA	40		

Table 2(b): List of PCR primers in primer mix B used for multiplex PCR

Primer name	Sequence (5'→ 3')	SEQ ID NO.	**Organism** *gene*	Amplicon size
PIV I HN-F2	CGA TAC GAC GGG CGT ACT AGC GAC AGG AAT TGG CTC AGA TAT G	41	**Parainfluenza 1** *hemagglutinin-neuraminidase*	382 bp
PIV I HN-R2	CGA TAC GAC GGG CGT ACT AGC GAC ATG ATC TCC TGT TGT CGT	42		
PIV III HN-F2	CGA TAC GAC GGG CGT ACT AGC GTC GAG GTT GCC AGG ATA TAG G	43	**Parainfluenza 3** *hemagglutinin-neuraminidase*	477 bp
PIV III HN-R2	CGA TAC GAC GGG CGT ACT AGC GGG ACT ATG AGA TGC CTG ATT GC	44		
PIV III 5'ND-F2	CGA TAC GAC GGG CGT ACT AGC GCA ACT ATT AGC AGT CAC ACT CG	45	**Parainfluenza 1** *5' noncoding region*	180 bp
PIV III 5'ND-R2	CGA TAC GAC GGG CGT ACT AGC GAA GTT GGC ATT GTG TTC AGT G	46		
HRhino 5'ND-F2	CGA TAC GAC GGG CGT ACT AGC GTC ATC CAG ACT GTC AAA GG	47	**Rhinovirus 89** *5' noncoding region*	423bp
HRhino 5'ND-R2	CGA TAC GAC GGG CGT ACT AGC GAA ACA GGA AAC ACG GAC ACC	48		
RSV Lpol-F2	CGA TAC GAC GGG CGT ACT AGC GCT CTA TCA TCA CAG ATC TCA GC	49	**RSV*-A** *L-polymerase*	388 bp
RSV Lpol-R2	CGA TAC GAC GGG CGT ACT AGC GCA TGA GTC TGA CTG GTT TGC	50		

RSVA MNN-F2	CGA TAC GAC GGG CGT ACT AGC GAC AAA GAT GGC TCT TAG CAA AG	51	**RSV*-A** *major nucleocapsid*	196 bp
RSVA MNN-R2	CGA TAC GAC GGG CGT ACT AGC GAC CCA GTG AAT TTA TGA TTA GC	52		
RSVB MNN-F2	CGA TAC GAC GGG CGT ACT AGC GAA AAC CAA CCC AAC CAA ACC	53	**RSV*-B** *major nucleocapsid*	248 bp
RSVB MNN-R2	CGA TAC GAC GGG CGT ACT AGC GGC ACA TCA TAA TTG GGA GTG TC	54		
WNV C-F 2	CGA TAC GAC GGG CGT ACT AGC GGC TCT CTT GGC GTT CTT CAG	55	**West Nile virus** *C and prM*	407 bp
WNV C-R2	CGA TAC GAC GGG CGT ACT AGC GTC ATT ACC AGC CGA CAG CAC	56		
WNV E-F2	CGA TAC GAC GGG CGT ACT AGC GCC GTC AGC GAT CTC TCC AC	57	**West Nile Virus** *E*	107 bp
WNV E-R2	CGA TAC GAC GGG CGT ACT AGC GCC TGT CCA CCA CTC CTT GTC	58		
WNV NS1-F2	CGA TAC GAC GGG CGT ACT AGC GGC TTG AAA GGG CAG TTC TGG	59	**West Nile Virus** *NS1*	150 bp
WNV NS1-R2	CGA TAC GAC GGG CGT ACT AGC GCA GGT CTC CGA TTG TGA TTG C	60		
coron229E MG-F2	CGA TAC GAC GGG CGT ACT AGC GCT CTG GTG TGT GGT GCT TAT A	61	**Coronavirus 229E** *membrane glycoprotein*	718 bp
coron229E MG-R2	CGA TAC GAC GGG CGT ACT AGC GCT CGG CAC GGC AAC TGT C	62		
coronOC43 MG-F2	CGA TAC GAC GGG CGT ACT AGC GAT GTG GAT GAC GTT TAG GTA	63	**Coronavirus OC43** *Membrane glycoprotein*	676 bp
coronOC43 MG-R2	CGA TAC GAC GGG CGT ACT AGC GGG TTG ATG GCA GTC GGT AA	64		
S pne lytA-F2	CGA TAC GAC GGG CGT ACT AGC GAA GAA GAG TTC ATG ACG GAC	65	***S. pneumoniae*** *Autolysin*	148 bp
S pne lytA-R2	CGA TAC GAC GGG CGT ACT AGC GTG GTT GTT TGG TTG GTT ATT CG	66		
S pne ply-F2	CGA TAC GAC GGG CGT ACT AGC GCC GAT GAC TTA TAG TAT TGA	67	***S. pneumoniae*** *pneumolysin*	129 bp
S pne ply-R2	CGA TAC GAC GGG CGT ACT AGC GAT AAT CTT GAT GCC ACT TAG C	68		
M pne CytP1-F2	CGA TAC GAC GGG CGT ACT AGC GGT TCT TCA GGC TCA GGT CAA TC	69	***M. pneumoniae*** *Cytadhesin P1 protein*	390 bp
M pne CytP1-R2	CGA TAC GAC GGG CGT ACT AGC GAC AGC GGT ATG TAC TGG TCA TA	70		
N men ctrA-F2	CGA TAC GAC GGG CGT ACT AGC GTG GGA ATA GTG TGC GTA TGC	71	***N. meningitidis*** *capsular transport protein*	195 bp
N men ctrA-R2	CGA TAC GAC GGG CGT ACT AGC GAC ATC ACC GCG ACG CAG CAA	72		
N men crag-F2	CGA TAC GAC GGG CGT ACT AGC GGA TTC CGC GAT GCC GAT G	73	***N. meningitidis*** *regularoty protein, crgA*	318 bp
N men crag-R2	CGA TAC GAC GGG CGT ACT AGC GCG CCC ATG TAT TTA GAG AAC CG	74		
B per PTXP-F2	CGA TAC GAC GGG CGT ACT AGC GCC GGC GTC GTG CGC GAA A	75	***B. pertussis*** *pertussis toxin promoter region*	361 bp
B per PTXP-R2	CGA TAC GAC GGG CGT ACT AGC GCA GCC ACG TCA GCC AGC C	76		
B per ptxS1-F3	CGA TAC GAC GGG CGT ACT AGC GGA GCG AAT ATC TGG CAC ACC	77	***B. pertussis*** *pertussis toxin S1 subunit*	337 bp
B per ptxS1-R3	CGA TAC GAC GGG CGT ACT AGC GGG GCC AGG TCT AGA ACG AAT	78		

C pne VD4-F2	CGA TAC GAC GGG CGT ACT AGC GTG GAG TAC AAT GGT CTC GAG C	79	***C. pneumoniae*** *major outer membrane protein VD4*	161 bp
C pne VD4-R2	CGA TAC GAC GGG CGT ACT AGC GTT TGC ATG AAG TCT GAG AAC GA	80		
C pne rpoB-F2	CGA TAC GAC GGG CGT ACT AGC GAC GGC ATT ACA ACG GCT AG	81	***C. pneumoniae*** *DNA directed RNA polymerase*	406 bp
C pne rpoB-R2	CGA TAC GAC GGG CGT ACT AGC GCA TCT TCT GGT AAT CCC TGT TC	82		
C pne VD2-F2	CGA TAC GAC GGG CGT ACT AGC GAC AGC GTT CAA TCT CGT TGG	83	***C. pneumoniae*** *major outer membrane protein VD2*	249 bp
C pne VD2-R2	CGA TAC GAC GGG CGT ACT AGC GAG AGA ATT GCG ATA CGT TAC AG	84		
S pyo speB-F2	CGA TAC GAC GGG CGT ACT AGC GCC TTA CAA CCT ATT GAC ACC TG	85	***S. pyogenes*** *pyrogenic exotoxin B*	371 bp
S pyo speB-R2	CGA TAC GAC GGG CGT ACT AGC GAC ACG AGA GCT ACC TGC AGA	86		
S pyo mef-F2	CGA TAC GAC GGG CGT ACT AGC GTT TAT ACA ATA TGG GCA GGG	87	***S. pyogenes*** *macrolide-efflux determinant (mefA, mefE)*	381 bp
S pyo mef-R2	CGA TAC GAC GGG CGT ACT AGC GTC GTA AGC TGT TCT TCT GGT AC	88		
S pyo ermB-F2	CGA TAC GAC GGG CGT ACT AGC GTC ATT GCT TGA TGA AAC TGA T	89	***S. pyogenes*** *erythromycin resistance methylase (ermB)*	244 bp
S pyo ermB-R2	CGA TAC GAC GGG CGT ACT AGC GTT GGA TAT TCA CCG AAC ACT AG	90		
S pyo ermTR-F2	CGA TAC GAC GGG CGT ACT AGC GCT TGT GGA AAT GAG TCA ACG G	91	***S. pyogenes*** *erm(TR)*	233 bp
S pyo ermTR-R2	CGA TAC GAC GGG CGT ACT AGC GAG GTA GCT ATA TTT CGC TTG AC	92		
B ant rpoB-F2	CGA TAC GAC GGG CGT ACT AGC GGA GCG TCT ACG TCC TGG TGA	93	***B. anthracis*** *RNA polymerase beta-subunit*	291 bp
B ant rpoB-R2	CGA TAC GAC GGG CGT ACT AGC GCA TTG GTT TCG CTG TTT TGA	94		
B ant pag-F2	CGA TAC GAC GGG CGT ACT AGC GTG GAA GAG TGA GGG TGG ATA C	95	***B. anthracis*** *protective antigen*	486 bp
B ant pag-R2	CGA TAC GAC GGG CGT ACT AGC GAA TAA TCC CTC TGT TGA CGA A	96		
B ant capB-F2	CGA TAC GAC GGG CGT ACT AGC GAG GAG CAA TGA GAA TTA CAC G	97	***B. anthracis*** *poly(D-glutamic acid) capsule*	311 bp
B ant capB-R2	CGA TAC GAC GGG CGT ACT AGC GCT AAG TTC CAA TAC TCT TGC	98		
VMVHA-F3	CGA TAC GAC GGG CGT ACT AGC GGC CGG TAC TTA TGT ATG TGC ATT	99	**Variola Major Virus** *hemagglutinin*	439 bp
VMVHA-R3	CGA TAC GAC GGG CGT ACT AGC GCA TCA TTG GCG GTT GAT TTA	100		
VMVcrmB-F3	CGA TAC GAC GGG CGT ACT AGC GGG GAA CAT ACG CTT CCA GAT	101	**Variola Major Virus** *cytokine response modifier B*	257 bp
VMVcrmB-R3	CGA TAC GAC GGG CGT ACT AGC GTT CCA CAT TTT GTT TGG GAA A	102		
EVLGV-F3	CGA TAC GAC GGG CGT ACT AGC GCC TTA TCC GAC TCG CAA TGT	103	**Ebola Virus** *L gene*	366 bp
EVLGV-R3	CGA TAC GAC GGG CGT ACT AGC GCA GTG TGA GGT TAT GTG GTG GA	104		
LVGPC-F4	CGA TAC GAC GGG CGT ACT AGC GTT GGT TGC GCA ATT CAA GT	105	**Lassa Virus** *GPC gene*	302 bp
LVGPC-R4	CGA TAC GAC GGG CGT ACT AGC GTG TTG TTC TTT GTG CAG GAG A	106		

F tul 13Kd-F2	CGA TAC GAC GGG CGT ACT AGC GTC GTA ATG TTA GCT GTA TCA TC	107	**F. tularensis** *13-kDa lipoprotein*	513 bp
F tul 13Kd-R2	CGA TAC GAC GGG CGT ACT AGC GTA CAT TAG CTG TCC ACT TAC CG	108		
F tul FopA-F2	CGA TAC GAC GGG CGT ACT AGC GGT GGG TGG TGG TCT TAA GTT T	109	**F. tularensis** *FopA*	192 bp
F tul FopA-R2	CGA TAC GAC GGG CGT ACT AGC GCT GGA TAT TAC CAG TGT CAT T	110		
Y pes cve-F2	CGA TAC GAC GGG CGT ACT AGC GAC TGA TAA AGG GGA GTG GAT A	111	**Y. pestis** *cve2155 sequence*	388 bp
Y pes cve-R2	CGA TAC GAC GGG CGT ACT AGC GCT CGC CTT GCT CTT TGA GC	112		
Y pes caf1-F2	CGA TAC GAC GGG CGT ACT AGC GGG ACA CAA GCC CTC TCT ACG	113	**Y. pestis** *Caf1*	564 bp
Y pes caf1-R2	CGA TAC GAC GGG CGT ACT AGC GTA GAT ACG GTT ACG GTT ACA G	114		
AthaNAC1-F5	CGA TAC GAC GGG CGT ACT AGC GCA TGG GAA GCT GTT TTG ATG	115	**A. thaliana** *NAC1*	497 bp
AthaNAC1-R5	CGA TAC GAC GGG CGT ACT AGC GCC CGA AGA ATT GTT CCA ATC	116		

*RSV: Respiratory syncytial virus

The RT reaction products were split up into two 10 µl volumes to be subjected to two different multiplex PCR reactions. Primer mix A contained 19 primer pairs and amplifies 18 gene targets from 3 different influenza A viruses, 1 influenza B virus, 3 serotypes of HAdVs, and one internal control (TIM). Primer mix B contains 38 primer pairs and amplifies the remaining 37 gene targets and the other internal control (NAC1). PCR reactions were performed in 50 µl volumes containing 20 mM Tris-HCl (pH 8.4), 50 mM KCl, 2 mM $MgCl_2$, 400 µM each of dATP, dCTP, dGTP, dUTP, 1 U of Uracil-DNA glycosylase, heat-labile (USB, Carlsbad, CA), 2 µM of primer L, 40 nM each of primers from mix A or 50 nM each of primers from mix B, 10 U of Platinum *Taq* DNA polymerase (Invitrogen Life Technologies, Carlsbad, CA), and 10 µl of RT product. The amplification reaction was carried out in Peltier Thermal Cycler- PTC240 DNA Engine Tetrad 2 (MJ Research Inc., Reno, NV) with initial incubation at 25°C for 10 min., preliminary denaturation at 94°C for 3 min., followed by 5 cycles of: 94°C for 30 sec., 50°C for 90 sec., 72°C for 120 sec., then 35 cycles of: 94°C for 30 sec., 64°C for 120 sec., and a final extension at 72°C for 5 min. The amplified products from both PCR reactions were combined into a single volume and subjected to purification and processing prior to hybridizing to the RPM v.1 chips (see below).

Example 6

Microarray hybridization and processing – The two PCR product mixtures were recombined after amplification for fragmentation and hybridization to the microarray. Microarray hybridization and processing were carried out according to the manufacturer's recommended protocol (Affymetrix Inc., Santa Clara, CA) with the following modification. Purified PCR products were fragmented at 37°C for 5 minutes, and then labeled with Biotin-N6-ddATP at 37°C for 30 minutes. Hybridization was carried out in a rotisserie oven at 45°C and 60 rev/min for 2 hours. After scanning, the GCOS software was used to reduce the raw image (.DAT) file to a simplified file format (.CEL file) with intensities assigned to each of the corresponding probe positions. Finally, the GDAS software was used to apply an embedded version of the ABACUS (Cutler et al., "High-throughput variation detection and genotyping using microarrays" *Genome Res.*, **11**, 1913-1925 (2001)) algorithm to produce an estimate of the correct base calls, comparing the respective intensities for the sense and anti-sense probe sets. To increase the percentage of

base calls, the parameters were adjusted to allow the most permissive base calling (shown below). The sequences from base calls made for each tiled region of the resequencing array then were exported from GDAS as FASTA-formatted files.

- Filter Conditions
  - No Signal threshold = 0.500 (default = 1.000000)
  - Weak Signal Fold threshold = 20000.000 (default = 20.000000)
  - Large SNR threshold = 20.000000 (default = 20.000000)
- Algorithm Parameters
  - Strand Quality Threshold = 0.000 (default = 0.000000)
  - Total Quality Threshold = 25.0000 (default = 75.000000)
  - Maximum Fraction of Heterozygote Calls = 0.99000 (default = 0.900000)
  - Model Type (0 = Heterozygote, 1 = Homozygote) = 0
  - Perfect Call Quality Threshold = 0.500 (default = 2.000000)
- Final Reliability Rules
  - Min Fraction of Calls in Neighboring Probes = 1.0000 (disables filter)
  - Min Fraction of Calls of Samples = 1.0000 (disables filter)

Example 7

Automatic Pathogen Identification Algorithm (Pathogen Identification based on NA sequence) – The raw output sequences generated from microarray hybridization and scanning were processed using an algorithm that identifies pathogens using sequence similarity comparisons against database records. A new software program, Computer-Implemented Biological Sequence-based Identifier system version 2 (CIBSI 2.0) was developed to analyze the results completely by incorporating in the tasks performed previously in the Resequencing Pathogen Identification (REPI) program (Lin et al., "Broad-spectrum respiratory tract pathogen identification using resequencing DNA microarrays" *Genome Res.*, **16**(4), 527-535 (2006)), and in addition performing decisions that were previously done manually. A broader discussion of this protocol, including an improved REPI algorithm is described in detail in US Patent Application No. 11/422,431, filed on 06 Jun 2006.

Example 8

Quantification of pathogens – The specificity of this assay was confirmed using various prototype strains and clinical samples. The results showed no discernible interference between targets. The analytical sensitivity of the RPM v.1 assay was then evaluated using serial ten-fold dilutions of the nucleic acid templates of the prototype strains. Table 1 shows the lowest dilution for each pathogen to which that pathogen was detectable. The results revealed a sensitivity range from 10 to 10^3 genomic copies per reaction for the prototype strains, which is comparable to the sensitivity of standard multiplex RT-PCR/PCR methods. It should be noted that genome copy number should not be equated to viable count (plaque forming units), as genome copy number is usually at least one, if not several orders of magnitude higher than viable count for respiratory pathogens. The capability of RPM v.1 to identify and discriminate between near genetic neighbors that was first demonstrated with more specific protocols has been reproduced with this protocol. The sequences generated from 17 different serotypes of human adenovirus (HAdV) revealed that this assay could differentiate various ARI-associated HAdV strains and proved that this assay

could be used for detecting a broad range of variants (Table 3). Cross hybridization of targets was observed on only HAdV *hexon* genes among different serotypes; but this does not interfere with positive identification of the correct targeted pathogens.

Table 3: Differentiation of various FRI-causing HAdVs with RPM v.1.

Sample	Strains	Strain identification by RPM v.1
HAdV-4	RI-67	HAdV-4 (AY594253)
HAdV-4 vaccine	CL68578	HAdV-4 vaccine (AY594254)
HAdV-4FS_Navy		HAdV-4FS_Navy (AY599835)
HAdV-4FS_AirForce		HAdV-4FS_AirForce (AY599837)
HAdV-5	adenoid 75	HAdV-5 (AY339865)
HAdV-1	adenoid 71	HAdV-1 (AY490817)
HAdV-2	adenoid 6	HAdV-2 (J01917)
HAdV-6	tonsil 99	HAdV-6 (DQ149613)
HAdV-7	Gomen	HAdV-7 (AY594255)
HAdV-7a vaccine	55142	HAdV-7 (AY 594256)
HAdV-7FS_Navy		HAdV-7FS_Navy (AY601634)
HAdV-3	GB	HAdV-3 (DQ086466)
HAdV-3FS_Navy		HAdV-3 US Navy Field Strain (AY 599836)
HAdV-16	Ch. 79	HAdV-16 (AY601636)
HAdV-21	AV-1645 [128]	HAdV-21 (AF492353)
HAdV-11	Slobitski	HAdV-11 (AY598970)
HAdV-14	De Wit	HAdV-14 (AY803294)

For sensitivity assessments, real-time PCR assays were conducted on iCycler or MYIQ™ instruments (Bio-Rad Laboratories, Hercules, CA) to determine the number of adenovirus genomes in each sample. The findings for the samples were compared to those for ten-fold serial dilution of HAdV-4 prototype genomic DNA templates of known copy number (10^1 to 10^6 copies) by using *fiber* specific primers Ad4F-F and Ad4F-R (Table 4). HAdV-4 genomic copy number was calculated by measuring DNA concentration from purified viral DNA and using the following conversion factor: 0.384 fg = a single adenoviral genome of ~35kb. Real-time PCR reactions were carried out in 25 µl reaction volumes containing 2.5 µl FastStart Reaction Mix SYBR Green I (Roche Applied Science, Indianapolis, IN), 20 mM Tris-HCl (pH 8.4), 50 mM KCl, 3 mM $MgCl_2$, 200 µM each of dATP, dTTP, dGTP, dCTP, 200 nM primers, and adenoviral genomic DNA (1-4 µl of clinical specimen or DNA extracts). The amplification reaction was carried out with preliminary denaturation at 94°C for 10 min. followed by 40 cycles of: 94°C for 20 sec., 60°C for 30 sec.

Similar assays were carried out to determine the genomic copy number of other pathogens by using specific primers (Table 4) and RT-PCR/PCR conditions as previously described (Stone et al., "Rapid detection and simultaneous subtype differentiation of influenza A viruses by real time PCR" *J. Virol. Methods*, **117**, 103-112 (2004); Hardegger et al., "Rapid detection of Mycoplasma pneumoniae in clinical samples by real-time PCR" *J. Microbiol. Methods*, **41**, 45-51 (2000); Corless et al., "Simultaneous detection of Neisseria meningitidis, Haemophilus influenzae, and Streptococcus pneumoniae in suspected cases of meningitis and septicemia using real-time PCR" *J. Clin. Microbiol.*, **39**, 1553-1558 (2001); Mölling et al., "Direct and rapid identification and genogrouping of meningococci and porA amplification by LightCycler PCR" *J. Clin. Microbiol.*, **40**, 4531-4535 (2002); Vabret et al., "Direct diagnosis of human respiratory coronaviruses 229E and OC43 by the polymerase chain reaction" *J. Virol. Methods*, **97**, 59-66 (2001)).

Table 4. List of PCR primers used for quantitative real-time PCR

Primer name	Sequence (5'→ 3')	SEQ ID NO.	**Organism** *gene*	Ampli-con size	Accession no. Reference
AMPfor1	GAC CAA TCC TGT CAC CTC TGA	117	**Influenza A** *matrix*	229	AF138708 Stone et al. 2004
AMPrev1	GTA TAT GAG KCC CAT RCA ACT	118			
BMA-F1	TCG GTG GGA AAG AAT TTG AC	119	**Influenza B** *matrix*	162	AF100378 This study
BMA-R1	TTC CTG ATA GGG GCT CTG TG	120			
Ad4F-F	ACA AGC AAG GAG ATA GCA TAG ATG	121	**Human Adenovirus 4** *fiber*	281	X76547 This study
Ad4F-R	GTA GGA GAA GGT GTA TGA GTT AGC	122			
C229E-MG-F1	ACC TGG GCT AAT TGG GAT TC	123	**Coronavirus 229E** *membrane glycoprotein*	222	AF304460 This study
C229E-MG-R1	AAT GCC TGT TGG AGC TTG TT	124			
COC43-MG-F1	GGC TTA TGT GGC CCC TTA CT	125	**Coronavirus OC43** *membrane glycoprotein*	284	M93390 Vabret et al., 2001
COC43-MG-R1	AAG ATG GCC GCG TAT TAT TG	126			
PIV1-HN-F2	GGC TCA GAT ATG CGA GAA CA	127	**Parainfluenza 1** *hemagglutinin-neuraminidase*	140	U70948 This study
PIV-HN-R2	TTG GTC CGG GTA ATA ATG AGA	128			
PIV3-HN-F2	CCA TAT GCG GCA TTA TAC CC	129	**Parainfluenza 3** *hemagglutinin-neuraminidase*	150	M20402 This study
PIV3-HN-R2	GCA GTC TCT CTG CGT TTT CC	130			
Rhino-5'-F1	TGC TTT ACC CAA GGC AAA AA	131	**Rhinovirus 89** 5' noncoding region	130	NC_001617 This study
Rhino-5'-R1	AGC CTC ATC TGC CAG GTC TA	132			
RSVA-N-F2	AAG ATG GCT CTT AGC AAA GTC AA	133	**RSV*-A** *major nucleocapsid*	100	M11486 This study
RSVA-N-R2	TAC TAT CTC CTG TGC TCC GTT G	134			
RSVB-N-F2	TGG GGC AAA TAC AAA GAT GG	135	**RSV*-B** *major nucleocapsid*	136	AF013254 This study
RSVB-N-R2	CAC ATC ATA ATT GGG AGT GTC AA	136			
PI549	CCA ACC AAA CAA CAA CGT TCA	137	***M. pneumoniae*** *P1 adhesion protein*	76	X07191 Hardegger et al., 2000
PI624	ACC TTG ACT GGA GGC CGT TA	138			
PI572$^{\varnothing}$	TCA ACT CGA ATA ACG GTG ACT TCT TAC CAC TG	139			
ply894	TGC AGA GCG TCC TTT GGT CTA T	140	***S. pneumoniae*** *pneumolysin*	81	M17717 Corless et al., 2001
ply974	CTC TTA CTC GTG GTT TCC AAC TTG A	141			
ply941$^{\varnothing}$	TGG CGC CCA TAA GCA ACA CTC GAA	142			
RS-F1	AAC AGA TGT AAG CAG CTC CGT TAT C	143	**RSV** *Fusion protein*	65	AF067125 Mentel et al. 2003
RS-F2	CGA TTT TTA TTG GAT GCT GTA CAT TT	144			
RS-F3$^{\varnothing}$	TGC CAT AGC ATG ACA CAA TGG CTC CT	145			
porA-F2	CGG CAG CGT (C/T) CA ATT CGT TC	146	***N. meningitidis*** *PorA (Porin)*	309	AF239810 Mölling et al. 2002
porA-R2	CAA GCC GCC TTC CTC ATA GC	147			

*RSV: Respiratory syncytial virus, Dual-labeled probe contains 6-carboxy-fluorescein (FAM) as the fluores-reporter dye at the 5' end, and the Black Hole Quenchers at the3' end.

Acession references:

Stone et al., "Rapid detection and simultaneous subtype differentiation of influenza A viruses by real time PCR" *J. Virol. Methods*, **117**, 103-112 (2004).

Vabret et al., "Direct diagnosis of human respiratory coronaviruses 229E and OC43 by the polymerase chain reaction" *J. Virol. Methods*, **97**, 59-66 (2001)

Hardegger et al., "Rapid detection of Mycoplasma pneumoniae in clinical samples by real-time PCR" *J. Microbiol. Methods*, **41**, 45-51 (2000)

Corless et al., "Simultaneous detection of Neisseria meningitidis, Haemophilus influenzae, and Streptococcus pneumoniae in suspected cases of meningitis and septicemia using real-time PCR" *J. Clin. Microbiol.*, **39**, 1553-1558 (2001)

Mentel et al., "Real-time PCR to improve the diagnosis of respiratory syncytial virus infection" *J. Med. Microbiol.*, **52**, 893-896 (2003)

Mölling et al., "Direct and rapid identification and genogrouping of meningococci and porA amplification by LightCycler PCR" *J. Clin. Microbiol.*, **40**, 4531-4535 (2002)

Example 9

Simultaneous detection and differentiation of respiratory pathogens – Previous studies have shown that, in addition to accurately identifying single pathogenic species, one of the salient benefits of using the RPM v.1 assay for pathogen detection is the ability to detect co-infections. In this study, the ability of the RPM v.1 assay to identify multiple pathogens simultaneously was further assessed by the preparation of various combinations of pathogen templates (Table 5 and 6). Serial dilutions of the template were used to evaluate the detection sensitivity and specificity for multiple pathogens. Nucleic acid templates containing 10^6-10^3 genome copies per reaction of each pathogen, HAdV-4, *S. pyogenes*, *M. pneumoniae*, and *Y. pestis* were mixed together and tested with RPM v.1 arrays. These results demonstrated that this assay allows reproducible sequence-based identification of all 4 pathogens even at the lowest concentration of 10^3 genomic copies per target per reaction (Table 5). The fact that there was no discernible interference in this complex mix further supported the robustness of the nucleotide base calling capability of the RA and the attendant identification algorithms, even in complex mixtures.

To further evaluate the effectiveness of this approach for multiple pathogen detection in a complex mixture, 3-7 cultured organisms were spiked at different titers [10^2-10^5 (cfu or pfu)/mL] into pooled nasal wash collected from volunteers, and 150 µL of the prepared samples were used for testing. Initial results revealed that this approach allowed unambiguous detection of 7 pathogens, HAdV-4, HAdV-7, *B. anthracis*, Influenza A-H1N1, Parainfluenza virus 1, RSV-A, *M. pneumoniae*, and *S. pyogenes* simultaneously at the lowest titer-100 cfu (pfu)/mL (Table 6). Further assessment with a different set of 7 pathogens showed that the RPM v.1 assay could simultaneously detect 6 of them. Among these, HAdV-4, *B. anthracis*, Influenza A-H1N1, RSV-A, and *M. pneumoniae* were detected at the lowest titer-100 cfu (pfu)/mL, and *S. pyogenes* was detected at 1000 cfu/mL (Table 6). *Y. pestis* could not be detected even at the highest concentrations. This was attributed to an inadequacies of the nucleic acid extraction protocol for the intact *Y. pestis* pathogen, since 1000 genome copies of *Y. pestis* could be detected when purified nucleic acid templates were used (Tables 1 and 5). For further confirmation, the RPM v.1 was tested with cultured organisms on same set of 4 pathogens that were tested using purified nucleic acid template (Table 5). Without failure, the results showed that the assay could reproducibly detect HAdV-4 and *M. pneumoniae* at 100 cfu (pfu)/mL, with less sensitivity for *S. pyogenes* (1000 cfu/mL) but not *Y. pestis*. When testing three pathogens simultaneously, in this case *B. anthracis*, Influenza A-H1N1, and HCoV-229E or RSV-A, the assay detected all three pathogens at titers as low as 100 cfu (pfu)/mL (Table 6). These results indicate that the RA-based approach is an effective means of detecting and typing various pathogens directly from nasal wash samples with the

benefit of high sensitivity and specificity for detecting co-infections of at least 7 pathogens. This approach will be useful for routine diagnosis and epidemic survey of these pathogens within the population, providing new information on the incidence of multiple pathogens.

Table 5: Simultaneous detection of multiple nucleic acid templates by RPM v.1

Genome copies	HAdV-4	GAS	MP	YP
10^6	+	+	+	+
10^5	+	+	+	+
10^4	+	+	+	+
10^3	+	+	+	+

Note: Sample was generated by mixing purified nucleic acid templates in TE buffer to create 10^6 genome copies/ul stock solution. Starting from this concentration, 10-fold serial dilutions in TE buffer were prepared.

Table 6: Simultaneous detection of multiple pathogens by RPM v.1

Titer	HAdV-4	GAS	MP	H1N1	RSV-A	HAdV-7	PIV1
10^5	+	+	+	+	+	+	+
10^4	+	+	+	+	+	+	+
10^3	+	+	+	+	+	+	+
10^2	+	+	+	+	+	+	+

Titer	HAdV-4	GAS	MP	H1N1	RSV-A	BA	YP
10^5	+	+	+	+	+	+	-
10^4	+	+	+	+	+	+	-
10^3	+	+	+	+	+	+	-
10^2	+	+	+	+	+	+	-

Titer	HAdV-4	GAS	MP	YP
10^5	+	+	+	-
10^4	+	+	+	-
10^3	+	+	+	-
10^2	+	-	+	-

Titer	BA	H1N1	HCoV-229E
10^5	+	+	+
10^4	+	+	+
10^3	+	+	+
10^2	+	+	+

Titer	BA	H1N1	RSV-A
10^5	+	+	+
10^4	+	+	+
10^3	+	+	+
10^2	+	+	+

Note: Samples were generated by mixing culture samples with pooled nasal washes collected from normal volunteers to generate 10^5 cfu(pfu)/ml. Starting from this concentration, 10-fold serial dilution with pooled nasal washes collected from normal volunteers was prepared. For each dilution, 150 µl of samples were used for the RPM v.1 process. BA- *B. anthracis* (Sterne), H1N1- influenza A-H1N1, HCoV229E- Human coronavirus 229E, HAdV- Human adenovirus, GAS- *S. pyogenes* (group A *Streptococcus*), MP- *M. pneumoniae*, PIV1: parainfluenza virus 1, RSV-respiratory syncytial virus, YP- *Y. pestis*. +: detected, -: not detected.

Example 10

Assessment of clinical specimens – After successfully demonstrating the capability of RPM v.1 assay

for pathogen detection, it was used for prospective and the retrospective diagnoses of infections causing ARI. Clinical specimens, collected primarily from military recruits presenting with ARI, were used to compare the utility of the microarray-based diagnostic to more established methods of respiratory pathogen detection. The samples (n = 101) consisted of throat swabs in viral transport medium with clinically documented respiratory illness. Samples were chosen randomly from sets that had tested positive for HAdV or influenza virus using CAP-certified diagnostic methods (cell culture and/or PCR) at NHRC. These were blinded (randomly renumbered and separated from the associated clinical records) and sent to the Naval Research Laboratory (NRL) for RPM v.1 testing. The compared experiments were conducted by two independent laboratories and the sample identities were revealed only after the results had been finalized. For influenza A virus, the RPM v.1 method showed a detection sensitivity of 87% and a specificity of 96% with respect to the initial diagnostic result, and an overall agreement of 92% (Table 7). For adenovirus, the RPM v.1 detection sensitivity was 97% with 97% specificity, for an overall agreement of 97% (Table 7). Upon further comparison of the RPM v.1 results with culture and PCR methods, the data showed comparable detection sensitivity and specificity to either culture or PCR assay (Table 8). The data suggested that the RPM v.1 had better sensitivity and specificity than culture vs. PCR, as might be expected since molecular methods are generally more sensitive than culture, and sequencing capability of the RPM v.1 method provided higher specificity than PCR (Table 9). This data further strongly demonstrated the ability of the microarray-based diagnostic to correctly identify clinically relevant influenza A virus strains in uncultured patient specimens.

Table 7: Evaluation of the RPM v.1 for Adenovirus, influenza A virus and negative control detection in clinical samples

	Adenovirus		Influenza A	
	PCR© +	PCR© -	Culture +	Culture -
RPM v.1 +	32	2*	39	2
RPM v.1 -	1	66	6¢	54
Sensitivity	97 %		87 %	
Specificity	97 %		96 %	
Clinical agreement	97 %		92 %	

©CAP-certified PCR; *One of the CAP-certified PCR negative samples was cultured for influenza A virus, RPM v.1 showed HAdV-4 and influenza A co-infection, the other negative sample was confirmed to have low titer HAdV-4; ¢3 influenza A culture positive samples could not be detected by quantitative real-time PCR as well, indicated that templates were degraded.

Table 8: Comparison of the RPM v.1 for influenza A virus positive and negative control detection in 40 clinical samples with culture and real-time PCR assays.

	Influenza A		Influenza A	
	Culture +	Culture -	PCR +	PCR -
RPM v.1 +	22	1	21	2
RPM v.1 -	3*	14	2	15
Sensitivity	88 %		91 %	
Specificity	93 %		88 %	
Clinical agreement	90 %		90 %	

Table 9: Comparison of the culture method for influenza A virus positive and negative control detection in 40 clinical samples with real-time PCR assay.

	Influenza A	
	Culture +	Culture -
PCR +	21	2
PCR -	4	13
Sensitivity	84 %	
Specificity	87 %	
Clinical agreement	85 %	

This study demonstrated the capability of this assay to identify the subtype of the influenza viruses and track genetic changes within influenza strains. This is especially critical for influenza epidemiology since antigenic drift is the mechanism by which influenza viruses escape from immunological pressure induced by previous natural exposures and vaccination. Analysis of *hemagglutinin* (HA) and *neuramindase* (NA) sequences generated from RPM v.1, recapitulated the known lineage changes occuring from 1999-2005 through antigenic drifting (Table 10). Seven influenza A/H3N2 clinical specimens collected prior to 2003-2004 influenza seasons were identified as belonging to the A/Panama/2007/99-like lineage, while 9 influenza A/H3N2 samples collected in 2003-2004 influenza season were clearly carrying signature A/Fujian/411/2002-like lineage nucleotide substitutions in the HA gene. The shift from an A/Fujian/411/2002-like strain to an A/California/7/2004-like strain is evident in the 18 influenza A/H3N2 samples collected in 2004-2005 influenza season. Three samples were identified as A/Fujian/411/2002-like strains while the rest showed signature California-like nucleic acid substitution in the HA gene. Two samples collected during the same period could only be identified as influenza A/H3N2. This was due to poor amplification and/or hybridization of targets, resulting in insufficient sequence information for strain level identification. Two influenza A/H1N1 samples collected in 2000-2001 were identified as closely related to A/New Caledonia/20/99.

Table 10: Influenza strain and lineage identification using RPM v.1

Sample ID	Collection Date	Representative Strain Identification (Accession no. of *HA* gene)	Lineage
10499	30-Sep-99	A/Charlottesville/10/99 (H3N2) (AF297094)	A/Panama/2007/99
41394	5-Jan-00	A/Sydney/5/97(H3N2) (AF180584)	A/Panama/2007/99
10552	11-Jan-00	A/France/2/00(H3N2) (AY633997)	A/Panama/2007/99
30491	13-Jan-00	A/New York/397/1999(H3N2) (CY006163)	A/Panama/2007/99
39002	12-Jan-01	A/Podgorica/4011/2001(H1N1) (AJ457863)	A/New Caledonia/20/99
70246	5-Feb-01	A/Madrid/1082/2001(H1N1) (AJ457886)*	A/New Caledonia/20/99
50833	24-Jan-02	A/New York/110/2002(H3N2) (CY000113)	A/Panama/2007/99
61596	2-Feb-02	A/Buenos Aires/722/01(H3N2) (AF534056)	A/Panama/2007/99
20694	7-Mar-02	A/New York/101/2002(H3N2) (CY001104)*	A/Panama/2007/99
31844	12-Nov-03	A/New York/41/2003(H3N2) (CY000153)*	A/Fujian/411/2002
70793	21-Nov-03	A/New York/18/2003(H3N2) (CY001061)*	A/Fujian/411/2002
51672	1-Dec-03	A/New York/28/2003(H3N2) (CY000009)	A/Fujian/411/2002
43269	1-Dec-03	A/New York/28/2003(H3N2) (CY000009)*	A/Fujian/411/2002
51673	1-Dec-03	A/New York/43/2003(H3N2) (CY000169)*	A/Fujian/411/2002
62416	16-Dec-03	A/New York/51/2003(H3N2) (CY001064)*	A/Fujian/411/2002
90781	17-Dec-03	A/New York/41/2003(H3N2) (CY000153)*	A/Fujian/411/2002
48930	12-Jan-04	A/Finland/305/2003 (H3N2) (DQ167271)	A/Fujian/411/2002
48934	13-Jan-04	A/New York/34/2003(H3N2) (CY0000431)	A/Fujian/411/2002
32323	18-Jan-05	A/Cheju/311/2002(H3N2) (AY589649)	A/Fujian/411/2002

32327	20-Jan-05	A/New York/464/2005(H3N2) (CY003648)	A/California/7/2004
49370	24-Jan-05	A/New York/378/2005(H3N2) (CY002016)	A/California/7/2004
52067	05-Jan-05	A/New York/244/2005(H3N2) (CY002080)*	A/California/7/2004
32329	21-Jan-05	A/New York/386/2004(H3N2) (CY002040)	A/California/7/2004
49369	22-Jan-05	A/New York/387/2004(H3N2) (CY002048)	A/California/7/2004
49376	1-Feb-05	A/New York/461/2005(H3N2) (CY006076)	A/California/7/2004
49377	02-Feb-05	A/New York/372/2004(H3N2) (CY002224)*	A/California/7/2004
49378	02-Feb-05	A/New York/359/2005(H3N2) (CY002000)	A/California/7/2004
62818	03-Feb-05	A/New York/359/2005(H3N2) (CY002000)	A/California/7/2004
52082	05-Feb-05	A/H3N2	N. D.
32349	14-Feb-05	A/New York/379/2004(H3N2) (CY002026)*	A/California/7/2004
52087	15-Feb-05	A/Aichi/143/2005(H3N2) (AB243872)	A/California/7/2004
52089	16-Feb-05	A/New York/396/2005(H3N2) (CY002072)	A/California/7/2004
49417	24-Feb-05	A/New York/373/2005(H3N2) (CY002456)*	A/California/7/2004
52095	25-Feb-05	A/Finland/170/03(H3N2) (AY661032)	A/Fujian/411/2002
52096	26-Feb-05	A/Finland/170/03(H3N2) (AY661032)	A/Fujian/411/2002
52099	28-Feb-05	A/Canterbury/67/2005(H3N2) (CY008059)	A/California/7/2004
49428	28-Feb-05	A/New York/382/2005(H3N2) (CY002032)*	A/California/7/2004
49432	01-Mar-05	A/New York/373/2005(H3N2) (CY002456)*	A/California/7/2004
49449	07-Mar-05	A/H3N2	N. D.

Note: * indicates only single strain was identified.

In addition to detecting single pathogens in the clinical samples, various co-infections such as HAdV-4/influenza A virus, HAdV-4/*S. pyogenes*, and influenza A virus/*M. pneumoniae* could be detected in clinical samples (data not shown). These co-infections were further verified using published type-specific PCR assays (Stone et al., "Rapid detection and simultaneous subtype differentiation of influenza A viruses by real time PCR" *J. Virol. Methods*, **117**, 103-112 (2004); Hardegger et al., "Rapid detection of Mycoplasma pneumoniae in clinical samples by real-time PCR" *J. Microbiol. Methods*, **41**, 45-5 (2000)) and in-house specific PCR primers (Table 4) (data not shown). Furthermore, the assay also detected *S. pneumoniae* in 26% and *N. meningitidis* in 16% of the clinical samples. The presence of *S. pneumoniae*, and *N. meningitidis* was verified by published species-specific quantitative real-time PCR assays (data not shown) in a subset of 40 of the clinical samples (limited due to the available volume of samples). It is well known that *S. pneumoniae*, and *N. meningitidis* are commensal bacteria in the mouth and upper respiratory system, so it is not surprising that these were commonly found in clinical samples. However, quantitative real-time PCR data showed that while most of the *S. pneumoniae* and *N. meningitidis* present in clinical samples was of low titer ($\leq 10^3$ genome copies/μl), 32% of the influenza-positive samples harbored a high titer of *S. pneumoniae* (7/25) or *N. meningitidis* (1/25) ($\geq 10^5$ genome copies/μL) (data not shown). The high titer bacteria present in these clinical samples is probably due to virally induced bacterial superinfection.

Example 11

Multiplex PCR Protocol with Primer L and LN – The following is a detailed protocol of example procedures.

Preparation work

1. ***Prepare TIM RNA from pSP64poly(A)-TIM***-- MEGASCRIPT® SP6 kit (Ambion, Cat # 1330)
   a) Linearized 1 μg of pSP64poly(A)-TIM with EcoRI enzymes

x μl	pSP64poly(A)-TIM
2 μl	10x EcoRI buffer

2 µl	EcoRI (NEB, Cat # R0101S)
(16-x) µl	H_2O
20 µl	Total volume

Incubate the reaction at 37°C for 5 hours.

b) Terminate the restriction digest by adding the following:

- 1/20th volume 0.5 M EDTA (1 µl)
- 1/10th volume of 3 M Na acetate (2 µl)
- 2 volumes of ethanol (40 µl)

c) Mix well and chill at –20°C for 20 min. Then pellet the DNA for 15 min in a microcentrifuge at top speed.

d) Remove the supernatant, re-spin the tube for a few seconds, and remove the residual fluid with a very fine-tipped pipet. Resuspend in 20 µl Nuclease Free water.

e) Place the RNA Polymerase Enzyme Mix on ice

f) Vortex the 10X Reaction Buffer and the 4 ribonucleotide solutions

g) (ATP, CTP, GTP, and UTP) until they are completely in solution.

h) Once thawed, store the ribonucleotides on ice, but ***keep the 10X Reaction Buffer at room temperature while assembling the reaction.***

i) All reagents should be microfuged briefly before opening to prevent loss and/or contamination of material that may be present around the rim of the tube.

j) Assemble the following transcription reaction at room temperature.

16 µl	Linearlized pSP64poly(A)-TIM
16 µl	NTPs (ATP, GTP, CTP, UTP-4µl each)
4 µl	10X Reaction Buffer
4 µl	Enzyme Mix
40 µl	Total volume

Incubate the reaction at 37°C for 6 hours.

k) Purify the RNA product with ProbeQuant™ G-50 Micro Column (Amersham, Cat #27533501)

l) Measure O.D. of the recovered RNA and dilute to make 60 fg/µl stock.

2. ***Prepare NAC1 DNA fragment from pSP64poly(A)-NAC1*** –PCR with platinum Taq DNA polymerase (Invitrogen, Cat # 10966-034)

1 µl	pSP64poly(A)-NAC1 (1ng/µl)
5 µl	10x PCR buffer
2 µl	50 mM $MgCl_2$
1 µl	10 mM dNTP mix
1 µl	SP6 (10 µM)
	5' –ATT TAG GTG ACA CTA TAG AAT-3'
1 µl	SP6 (10 µM)
	5' –CAG GAA ACA GCT ATG ACC ATG-3'
0.5 µl	Platinum Taq polymerase

38.5 µl H_2O

50 µl Total volume

Run the following PCR program:

94°C – 3 minutes

40 cycles of:

94°C – 30 seconds

50°C – 30 seconds

72°C – 40 seconds

72°C – 5 minutes

4°C – forever

Purified PCR product-QIAquick® PCR purification kit (Qiagen, Cat # 28106)

a) Add 250 µl of Buffer PB to 50 µl PCR sample.

b) Place a QIAquick spin column in a provided 2 ml collection tube.

c) To bind DNA, apply the sample to the QIAquick column and centrifuge for 30–60 s.

d) Discard flow-through. Place the QIAquick column back into the same tube.

e) To wash, add 0.75 ml Buffer PE to the QIAquick column and centrifuge for 30–60 s.

f) Discard flow-through and place the QIAquick column back in the same tube.

g) Centrifuge the column for an additional 1 min.

h) Place QIAquick column in a clean 1.5 ml microcentrifuge tube.

i) To elute DNA, add 50 µl Buffer EB (10 mM Tris·Cl, pH 8.5) or H2O to the center of the QIAquick membrane, let the column stand for 1 min, and then centrifuge the column for 1 min.

j) Measure O.D. of the PCR product and dilute to make 60 fg/µl stock.

3. Make 1 ml of 1 µM primer mix A stock by mixing 10 µl of 100 µM oligos stock (Table 2(a)) and add water to 1 ml. Mix well, then split to 100µl aliquots.
4. Make 1 ml of 1 µM primer mix B stock by mixing 10 µl of 100 µM oligos stock (Table 2(b)) and add water to 1 ml. Mix well, then split to 100µl aliquots.

Multiplex PCR

1. **Nucleic Acid Extraction**- MASTERPURE™ DNA purification kit (Epicentre, Cat #MC89010).

a) Add 100 µl of 1X PBS to 50 µl of Nasal Washes.

b) Add 150 µl 2X T & C lysis solution with 1 µl of proteinase K.

c) Incubate at 65°C for 15 minutes, vortex every 5 minutes.

d) Incubate on ice or 4°C for 3- 5 minutes.

e) Add 150 µl MPC solution to the sample, vortex for 10 seconds.

f) Spin at maximum speed for 10 minutes.

g) Transfer the supernatant to a fresh 1.5 ml tube, then, add 500 µl isopropanol, mix well.

h) Spin at maximum speed at 4°C for 10 minutes. Discard the supernatant, then wash with 80% alcohol twice.

i) Dry the pellet and resuspend in 8 µl nuclease free water.

2. **Reverse Transcription with primer LN**-Invitrogen Superscript III (Invitrogen, Cat. #18080-093)

NA from step 1	8 µl	
primer LN (40 µM)		1 µl
5'-CGA TAC GAC GGG CGT ACT AGC GNN NNN NNN N-3'		
10 mM dNTPs		1 µl
TIM (60 fg/µl)		1 µl
NAC1 (60 fg/µl)	1 µl	
Total volume		12 µl

Incubate at 65C for 5 minutes, then put on ice for >1 minute

Add the following reaction mix to the tube and mix gently by pipeting:

5X First-Strand buffer	4 µl
0.1 M DTT	2 µl
RNaseOUT	1 µl
SuperScript III	1 µl
Total volume	8 µl

Run the following program on PCR machine:

25°C – 10 minutes

50°C – 50 minutes

85°C – 5 mintues

3. **Split Multiplex PCR with primer L**

a. Reaction A:

10X PCR buffer	5 µl	
50 mM MgCl2	4 µl	
50X dNTPs		2 µl
primer L (100 µM)		1 µl
5'-CGA TAC GAC GGG CGT ACT AGC G-3'		
Primer A mix (1 µM)		2 µl
5x Q-solution		5 µl
RT template (from step 2)	10 µl	
Platinum taq		2 µl
Nuclease-free water		18 µl
UDG		1 µl
Total Volume		50 µl

b. Reaction B:

10X PCR buffer	5 µl	
50 mM MgCl2	4 µl	
50X dNTPs		2 µl

primer L (100 µM)	1 µl
5'-CGA TAC GAC GGG CGT ACT AGC G-3'	
Primer B mix (1 µM)	2.5 µl
5x Q-solution	5 µl
RT template	10 µl
Platinum taq	2 µl
Nuclease-free water	17.5 µl
UDG	1 µl
Total Volume	50 µl

Run the following PCR program:

94°C – 3 minutes

5 cycles of:

94°C – 30 seconds

50°C – 90 seconds

72°C – 2 minutes

35 cycles of:

94°C – 30 seconds

64°C – 2 minutes

72°C – 5 minutes

4°C – forever

Array preparation

Tag IQ-EX PCR- 1.0 kb Tag IQ-EX or 7.5 kb Tag IQ-EX

1.0 kb Tag IQ-EX PCR

Forward primer (1kb)	3 µl
Reverse primer	3 µl
Tag IQ-EX	5 µl
$MgCl_2$ (50 mM)	5 µl
dNTP (10 mM)	2 µl
10X PCR Buffer	10 µl
Platinum Taq DNA polymerase	1 µl
Water	71 µl
Total volume	100 µl

- 94°C, 3'
- 30 cycles of 94°C, 30"; 68°C, 30"; 72°C, 40"
- 72°C, 10'

7.5 kb Tag IQ-EX PCR

Forward primer (7.5 kb)	3 µl
Reverse primer	3 µl

Tag IQ-EX	5 µl
dNTP (LA PCR kit)	16 µl
10X PCR Buffer (LA PCR kit)	10 µl
TaKaRa Taq	1 µl
Water	62 µl
Total volume	100 µl

- 94°C, 3'
- 30 cycles of 94°C, 30"; 68°C, 7'30"
- 68°C, 10'

Purified PCR products (Tag IQ-EX and multiplex PCR)-QIAquick® PCR purification kit (Qiagen, Cat # 28106)

a) Add 500 µl of Buffer PB to 100 µl PCR sample (combine reaction A and B).
b) Place a QIAquick spin column in a provided 2 ml collection tube.
c) To bind DNA, apply the sample to the QIAquick column and centrifuge for 30–60 s.
d) Discard flow-through. Place the QIAquick column back into the same tube.
e) To wash, add 0.75 ml Buffer PE to the QIAquick column and centrifuge for 30–60 s.
f) Discard flow-through and place the QIAquick column back in the same tube.
g) Centrifuge the column for an additional 1 min.
h) Place QIAquick column in a clean 1.5 ml microcentrifuge tube.
i) To elute DNA, add 40 µl Buffer EB (10 mM Tris·Cl, pH 8.5) or H2O to the center of the QIAquick membrane, let the column stand for 1 min, and then centrifuge the column for 1 min.
j) Measure O.D. of the PCR product.

Fragmentation and Labeling

1. Set up one tube per sample for fragmentation, add EB buffer to final volume 35 µl for each reaction. Treat Tag IQ-EX as one sample

Line 1	Total µg of product to add to an array	1.4 µg
Line 2	Number of fragmentation reagent U required to fragment DNA	Line 1× 0.15 = 0.21 U
Line 3	Activity of Fragmentation reagent (U/µl)	3 U/µl
Line 4	Volume of Fragmentation reagent required for each reaction (µl)	Line 2 ÷ line 3 = 0.07 µl
Line 5	Volume of water required for each reaction (µl)	3.3- line 4 = 3.23 µl

2. On ice prepare the fragmentation cocktail

10X fragmentation buffer	4.3 µl
water	3.23 µl
Fragmentation reagents	0.07 µl
Total volume	7.6 µl

3. Chilled the fragmentation cocktail on ice, then added 7.6 µl to each DNA prepared from step 1 & 2.
4. Run the following program.

- 37°C, 5'
- 95°C, 10'
- 4°C, hold

5. Prepare the labeling cocktail (per reaction)

Tdt buffer (5X)	12 µl
GeneChip DNA labeling reagent (5 mM)	2 µl
TdT (30U/µl)	3.4 µl
Total	17.4 µl

6. Add 17.4 µl of the labeling cocktail to one each of reactions and control fragmented PCR product.
7. Run the following program.
   - 37°C, 30'
   - 95°C, 5'
   - 4°C, hold

Hybridization

1. Turn on the hybridization oven set at 45°C, warm the chips to room temperature.
2. Prepare the pre-hybridization solution.

1% Tween-20	2 µl
1 M Tris, pH 7.8	2 µl
Water	196 µl
Total volume (per chip)	200 µl

3. Pre-hybridize the chips with pre-hybridization buffer at 45°C.
4. Assemble the hybridization master mix.

Tag IQ-EX* (fragmented 0.26 µg)	1.9 µl
5 M TMAC	132 µl
1 M Tris, pH 7.8	2.2 µl
1% Tween-20	2.2 µl
Herring sperm DNA (10 mg/ml)	2.2 µl
Acetylated BSA	2.2 µl
Control oligo B2	3.4 µl
Water	13.9 µl
Final volume (per chip)	160 µl

* Use the following calculation to determine how much fragmented Tag IQ-EX for hybridization master mix.

- Purified PCR product conc. (e.g. 100 ng/µl) x 35 µl = 3500 ng
- Final volume after fragmentation and labeling is 60 µl
- Final conc. of fragmented Tag IQ-EX = 58.3 ng/µl
- You will need 260 /58.3 = 4.4658.3µl

5. Add 160 µl to 60 µl labeled samples. Run the following program.
   - 95°C, 5'

45°C, 5

6. Remove the pre-hybridization buffer from the chip and fill with hybridization mix.
7. Hybridize overnight at 45°C, 60 rpm.

Washing and Staining

1. Prepare Washing buffer A & B

Wash A	
20X SSPE	300 ml
10% Tween-20	1 ml
Water	699 ml

Filter through a 0.2 μm filter and stored capped at room temperature.

Wash B	
20X SSPE	30 ml
10% Tween-20	1 ml
Water	969 ml

Filter through a 0.2 μm filter and stored capped at room temperature.

2. Prepare SAPE stain solution (each chip)

20X SSPE	360 μl
1% Tween-20	12 μl
50 mg/ml acetylated BSA	50 μl
SAPE	12 μl
DI water	766 μl

Mix well and divide to two aliquots of 600 μl (stain 1 & stain 3)

3. Prepare Antibody solution (each chip)

20X SSPE	180 μl
1% Tween-20	6 μl
50 mg/ml acetylated BSA	25 μl
10 mg/ml Normal goat IgG	6 μl
0.5 mg/ml biotinylated antibody	3.6 μl
DI water	379.4 μl
Final volume	600 μl

4. Run wash protocol-DNAARRAY WS4.

Unlike traditional methods, the optimized RPM v.1 assay may not only identify pathogens, but may also provide sequence information, allowing a large number of pathogens to be detected and phylogenetically categorized in the same assay. The sequence information demonstrated the capability of RPM v.1 for identifying a broad range of variants (*e.g.* HAdVs) which is a powerful tool for genetic variation analysis of the circulating and emerging viruses (*i.e.* influenza). This is also useful in tracking the movement of known variants. This utility was clearly demonstrated in the Influenza A positive clinical samples showing the lineages change from A/ A/Panama/2007/99-like strains (prior 2003 influenza season) to A/Fujian/411/2002-like strain in 2003-2004 influenza season, then to A/California/7/2004-like strains in 2004-2005 influenza season. Only one M gene (H1N1) sequence, which is

relatively conserved among influenza A viruses, was tiled on the RPM v.1. But the M gene ProSeq was still able to detect homologous regions of disparate subtypes, allowing correct differentiation (Table 10). This M gene ProSeq would theoretically allow detection of any other type of influenza virus for which antigenic HA and NA sequences were not tiled on the array.

This study demonstrates that this system may exhibit excellent clinical sensitivity and specificity, the ability to resolve complex co-infections without a loss of sensitivity, and the sensitivity is similar to all 26 targeted pathogens and potential biowarfare agents. In contrast to both culture and PCR assays, this assay platform showed comparable detection sensitivity and specificity for both HAdV and influenza A virus (Table 7). The data supports the feasibility of using the RPM v.1 system as a diagnostic tool to correctly identify and type clinically relevant adenovirus and influenza A virus strains in direct (uncultured) clinical specimens, in a manner that correlates well with conventional detection methods.

Obviously, many modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that the claimed invention may be practiced otherwise than as specifically described. Any reference to claim elements in the singular, e.g., using the articles "a," "an," "the," or "said" is not construed as limiting the element to the singular.

CLAIMS

What is claimed is:

1. A method comprising:
providing a biological sample suspected of containing one or more pathogen nucleic acids from a predefined set of pathogens;
adding to the sample a plurality of PCR primers corresponding to genes found in the predefined set of pathogens;
wherein the primers include at least one primer pair for each pathogen;
wherein the primers comprise a tail sequence that is not homologous to the DNA of any of the predefined set of pathogens or to any background DNA in the sample; and
performing a polymerase chain reaction on the sample to amplify a subset of the nucleic acids that correspond to the genes;
wherein the concentration of at least one primer in the polymerase chain reaction is no more than about 100 nM.

2. The method of claim 1, wherein the concentration of each primer in the polymerase chain reaction is no more than about 100 nM.

3. The method of claim 1, wherein the tail sequence is CGATACGACGGGCGTACTAGCG (SEQ ID NO.1).

4. The method of claim 1, wherein the tail sequence is CGATACGACGGGCGTACTAGCGNNNNNNNNN (SEQ ID NO.2).

5. The method of claim 1, further comprising:
extracting the nucleic acids from a clinical sample to produce the biological sample.

6. The method of claim 5, wherein the clinical sample comprises a nasal wash, a throat swab, sputum, blood, or an an environmental sample.

7. The method of claim 5,
wherein the clinical sample from an organism; and
tail sequence that is not homologous to the DNA of the species of the organism.

8. The method of claim 7, wherein the organism is human.

9. The method of claim 1, wherein the pathogens are respiratory pathogens.

10. The method of claim 1, wherein the pathogens are enteric pathogens or biothreat agents.

11. The method of claim 1, wherein the amplified nucleic acids include a sequence of less than 200 nucleotides and a sequence of more than 2000 nucleotides.

12. The method of claim 1, wherein the tail sequence reduces the formation of primer-dimers.

13. The method of claim 1, wherein the PCR primers include at least 50 different primers.

14. The method of claim 1,

wherein adding the plurality PCR primers and performing the polymerase chain reaction are each performed on a plurality of aliquots of the biological sample;

wherein a different plurality PCR primers is used for each aliquot; and

wherein the aliquots are combined after the PCR reactions.

15. The method of claim 1, further comprising:

contacting the sample to a microarray comprising a plurality of nucleic acid sequences that are complementary to at least portions of the amplified nucleic acids; and

allowing the amplified nucleic acids to hybridize to complementary nucleic acids.

16. The method of claim 15, wherein the complementary nucleic acids are from 25- to 29-mers.

17. The method of claim 15, wherein the complementary nucleic acids include a perfect match probes to at least one of the amplified nucleic acids and three different single nucleotide polymorphisms of the center position of each perfect match probe.

18. The method of claim 15, further comprising:

detecting which amplified nucleic acids are hybridized to the complementary nucleic acids.

19. The method of claim 18, further comprising:

identifying the pathogen based on which amplified nucleic acids are detected.

20. The method of claim 19, wherein the identification is based upon pattern recognition.

21. The method of claim 19, wherein the identification is based on sequencing of the amplified nucleic acids.

22. The method of claim 18, wherein the identification includes the strain of the pathogen.