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*PHSA*

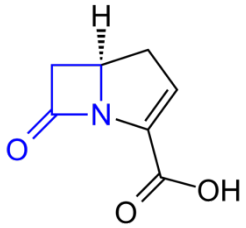
# Carbapenemase Producing Organisms: How BC Fairs Amidst Its Global Emergence.

# Objectives

- What are Carbapenemase Producing Organisms?
- Overview of global and national activities
- Update on BC activities
- Challenges and next steps

# What are Carbapenemase Producing Organisms (CPO)?

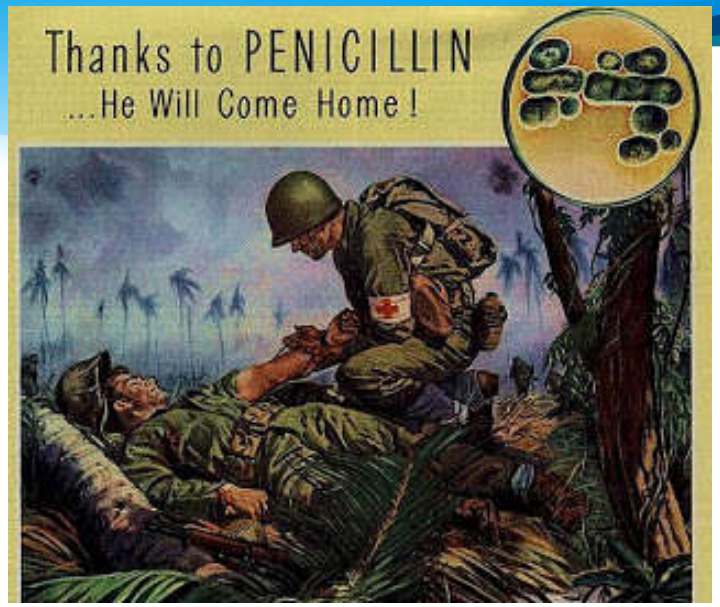
- Carbapenemases are a class of enzymes that inactivate carbapenem antibiotics by hydrolysing them.
- Carbapenem antibiotics, often referred to as “last resort antibiotics”:
  - Imipenem
  - Meropenem
  - Ertapenem



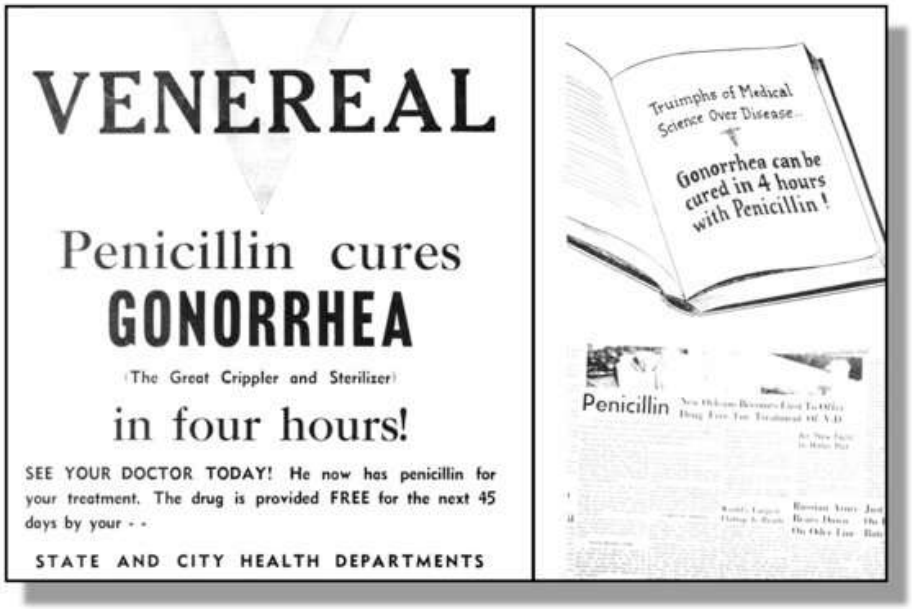

- Carbapenemases most commonly in *E. coli* and *Klebsiella spp*., (Enterobacterieaceae) but have also been found in other Gram-negative species.

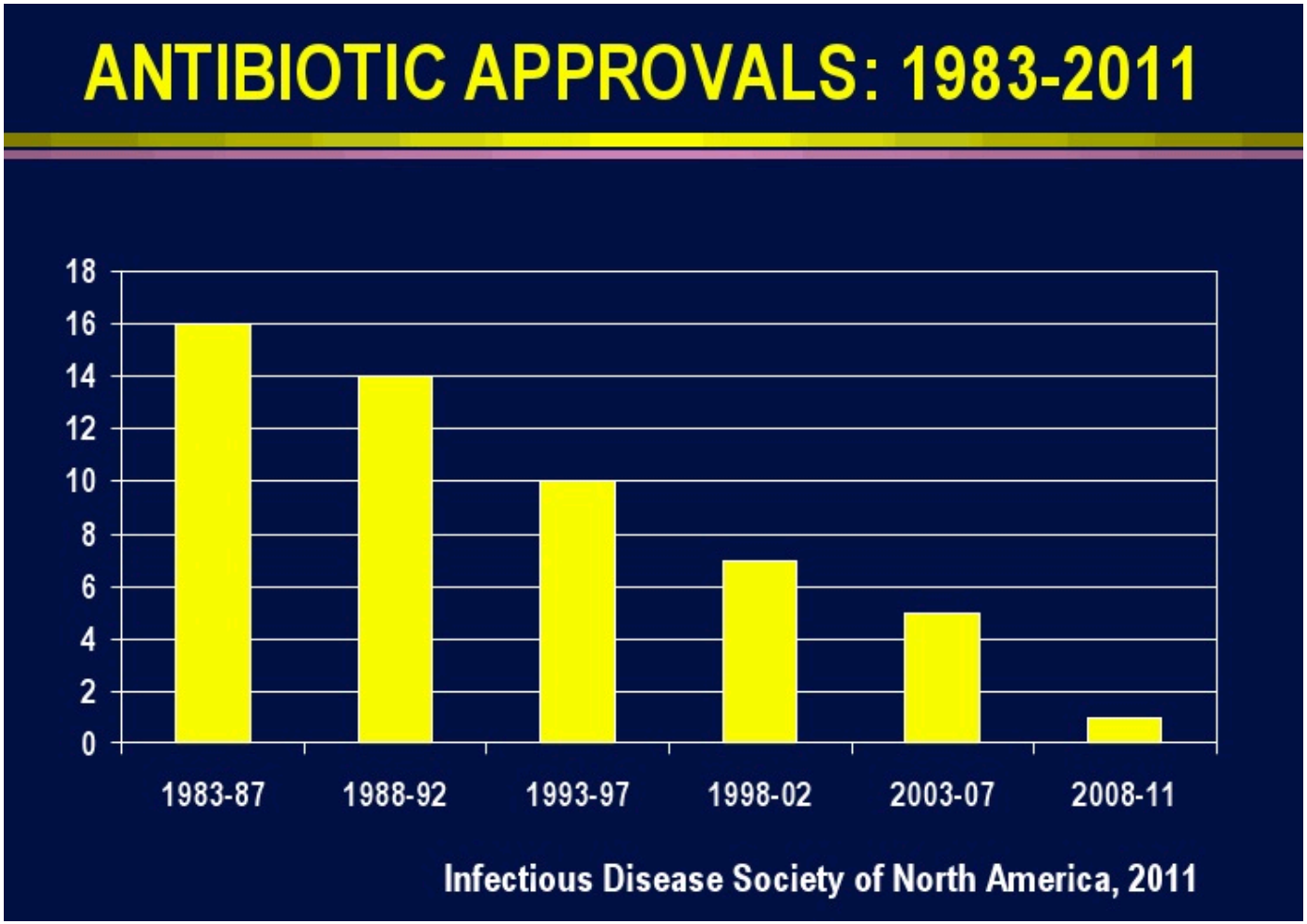
# Terminology

- CRE: Carbapenem resistant Enterobacteriaceae (mechanism unknown)
- CPE: Carbapenemase producing Enterobacteriaceae (mechanism known)
- CPO: Carbapenemase producing organisms (Enterobacteriaceae plus other non-fermentors)
- Carbapenem: A broad-spectrum class of antibiotics
- Enterobacteriaceae: A family of Gram-Negative bacteria (e.g. *E. coli, Klebsiella pneumoniae*, etc)
- Non-fermentors: *Pseudomonas sp, Acinetobacter sp*, etc

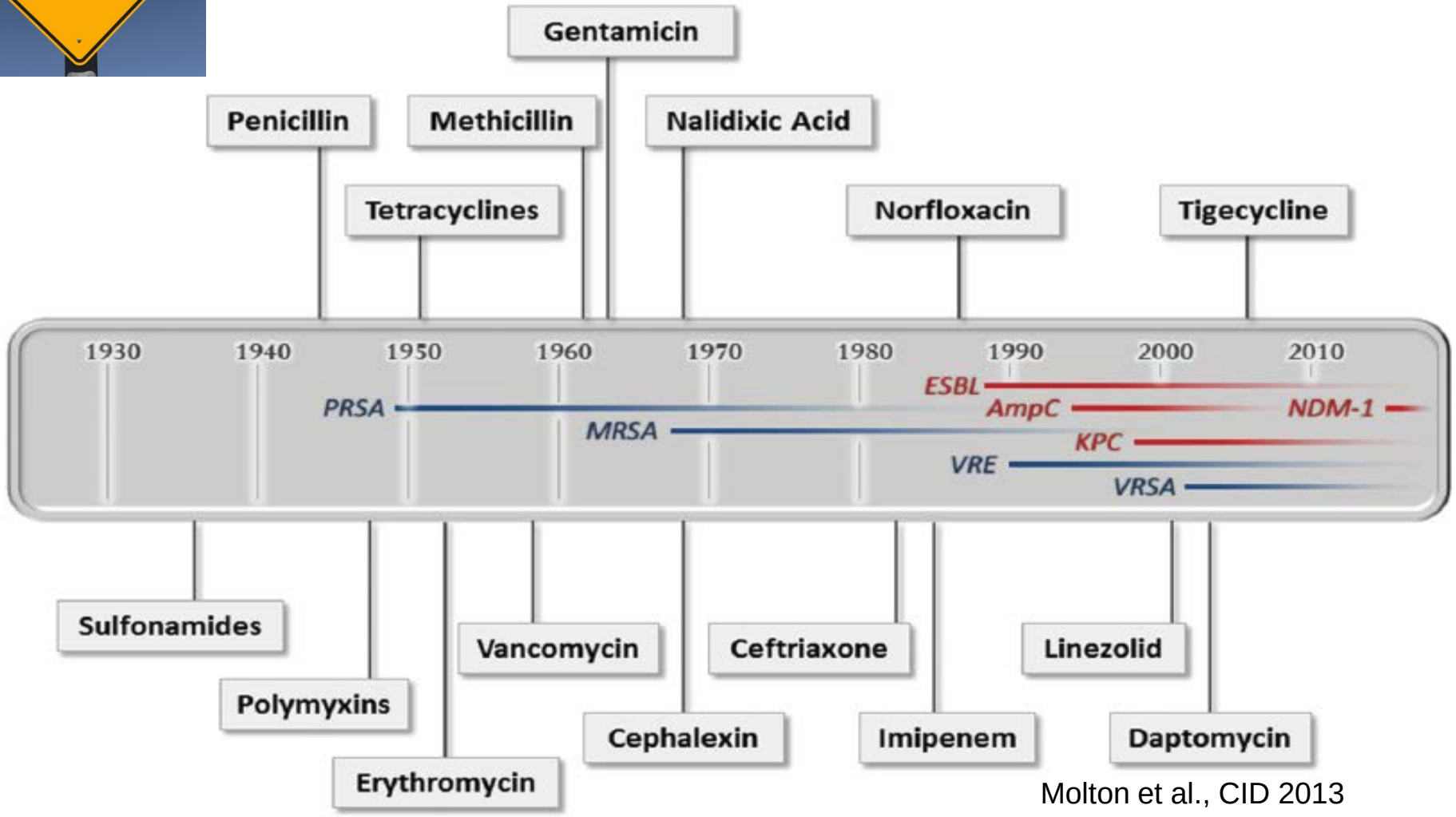



We are loosing are miracle drugs and research/industry are not rising up to the challenge





ANTIBIOTIC APPROVALS: 1983-2011
18
16
14
12
10
8
6
4
2
0
1983-87
1988-92
1993-97
1998-02
2003-07
2008-11
Infectious Disease Society of North America, 2011


# Antibiotic Timeline and Emergence of Resistant Bacteria




Molton et al., CID 2013

# ’ eta-lactamase Family

| Molecular Class | Types |
|---|---|
| A | TEM, SHV, CTX-M KPC, GES, SMC, IMI, PER, NMC-A, SFO, SFC, BIC, IBC |
| B | NDM-1, IMP, VIM, GIM, SPM, SIM, DIM, AIM, KHM |
| C | CMY, ACT, FOX, MOX |
| D | OXA, PSE OXA-48 |

ANTIMICROBIAL AGENTS AND CHEMOTHERAPY, Dec. 2009, p. 5046–5054 Vol. 53, No. 12
0066-4804/09/$12.00 doi:10.1128/AAC.00774-09


# Characterization of a New Metallo-β-Lactamase Gene, *bla*$_{NDM-1}$, and a Novel Erythromycin Esterase Gene Carried on a Unique Genetic Structure in *Klebsiella pneumoniae* Sequence Type 14 from India[▽]

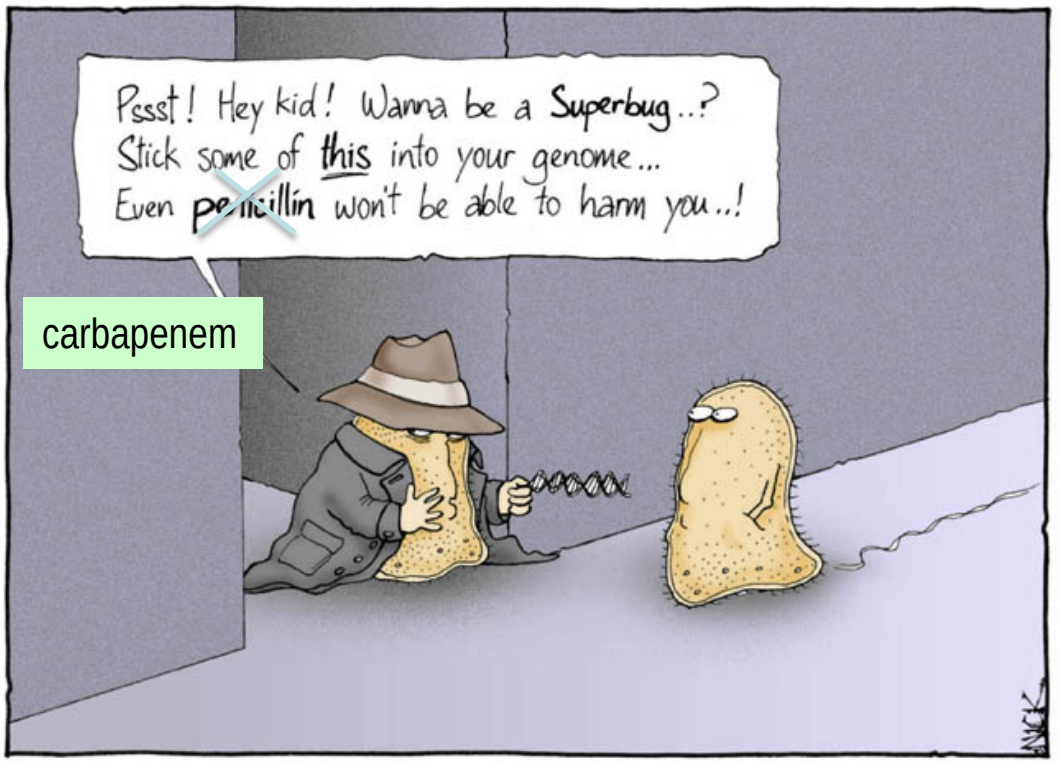
Dongeun Yong,[1,2] Mark A. Toleman,[2] Christian G. Giske,[3] Hyun S. Cho,[4] Kristina Sundman,[5] Kyungwon Lee,[1] and Timothy R. Walsh[2]*

*Yonsei University College of Medicine, Research Institute of Antimicrobial Resistance, Seoul, Republic of Korea[1]; Department of Medical Microbiology, Cardiff University, Cardiff, United Kingdom[2]; Clinical Microbiology, MTC—Karolinska Institutet, Karolinska University Hospital, Stockholm, Sweden[3]; Yonsei University College of Life Science and Biotechnology, Seoul, Republic of Korea[4]; and Department of Clinical Microbiology, Örebro University Hospital, Örebro, Sweden[5]*

- New metallo-² -lactamase (Ambler Class B), shares little with others in the same class
- NDM-1 found on plasmid therefore, transferable
- Other broad resistance genes carried on plasmid
- NDM resistant to all ² -lactams and many other antibiotics

# Transferable Carbapenemase genes (on plasmid)

- highly transmissible: Serious Infection Control implications

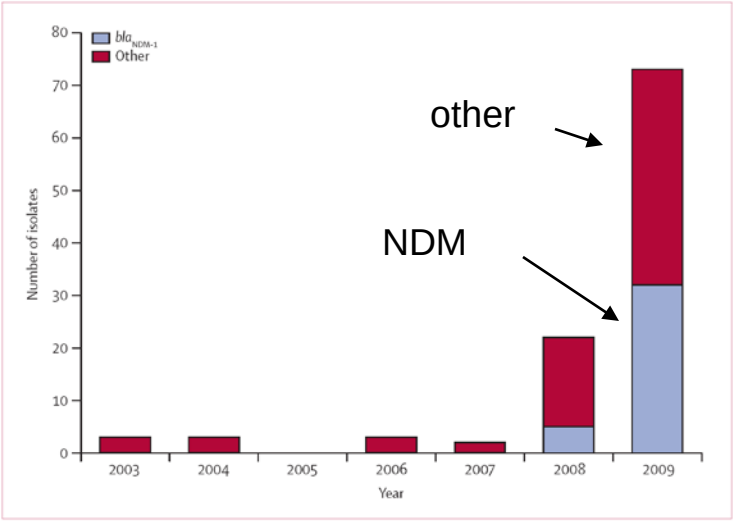



- Can be shared between different species (Enterobacteriaceae, other gram-negative bacilli)

# New Delhi Metallo-beta-lactamase (NDM-1)

- Reports in 2008 of Swedish and UK travelers to Indian subcontinent
- Since then, reports of high endemicity in Indian, Pakistan and Bangladesh hospitals
- NDM-1 genes in sewage and water reservoirs in some Indian cities
  - 51/171 (30%) waste water seepage
  - 2/50 (4%) communal drinking water samples

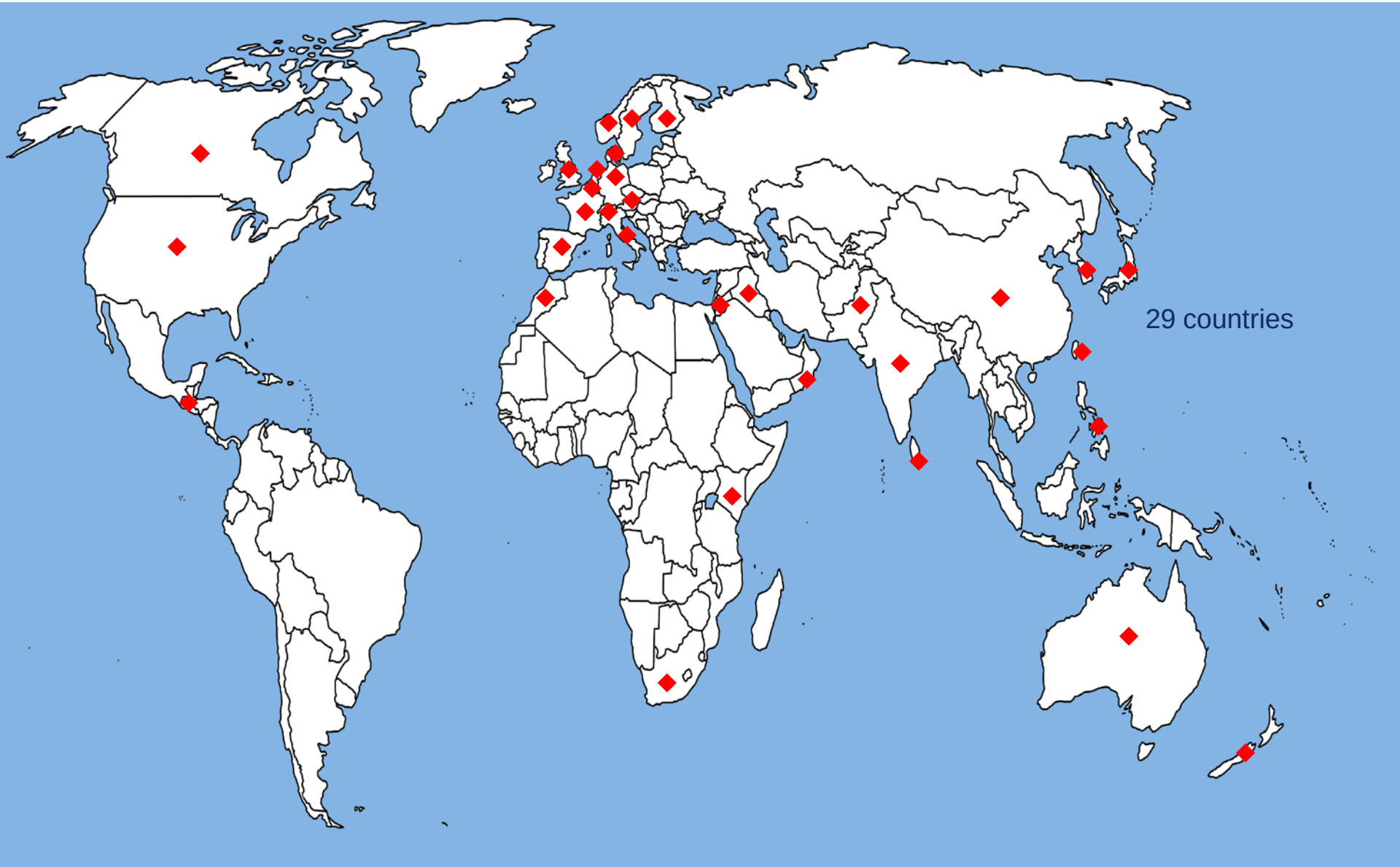
Walsh et al. The Lancet Infectious Diseases, 2011, 11: 355-62




CRE in UK 2003-2009

Total of 70 isolates in 2009
With 35 NDM

# Global Distribution NDM-1



# First introductions of NDM-1 to Canada

- 76 yo female (*E. coli, K. pneumoniae* UTI) was hospitalized in India, direct transfer to a BC Hospital early 2010.
  First BC case.
  Mulvey et al. 2011. EID 17:103-6.
- 36 yo male hospitalized in India *E. coli* UTI, 2010. Successfully treated with fosfomycin/ert. Peirano et al. 2011. EID 17:242-4.
- 36 yo female Brampton, Ontario, *Kp* urine isolate, hospitalized in India. Tijet et al. 2011. EID 17:306-7.

# NDM in Canada: 2012-2013 Several reports on CRE outbreaks

- **Borgia *et al.*** Clinical Infectious Diseases
  - 5 *K. pneumoniae* and *E.coli* all epi linked in a tertiary care community hospital in Brampton, Ont. No travel history.

- **Chris Lowe *et al*.**, Infect Control Hosp Epidemiol.
  - Transmission in a Toronto Hospital
  - 2 index cases with NDM1 *K. pneumoniae*
  - Transmission to 7 patients was identified

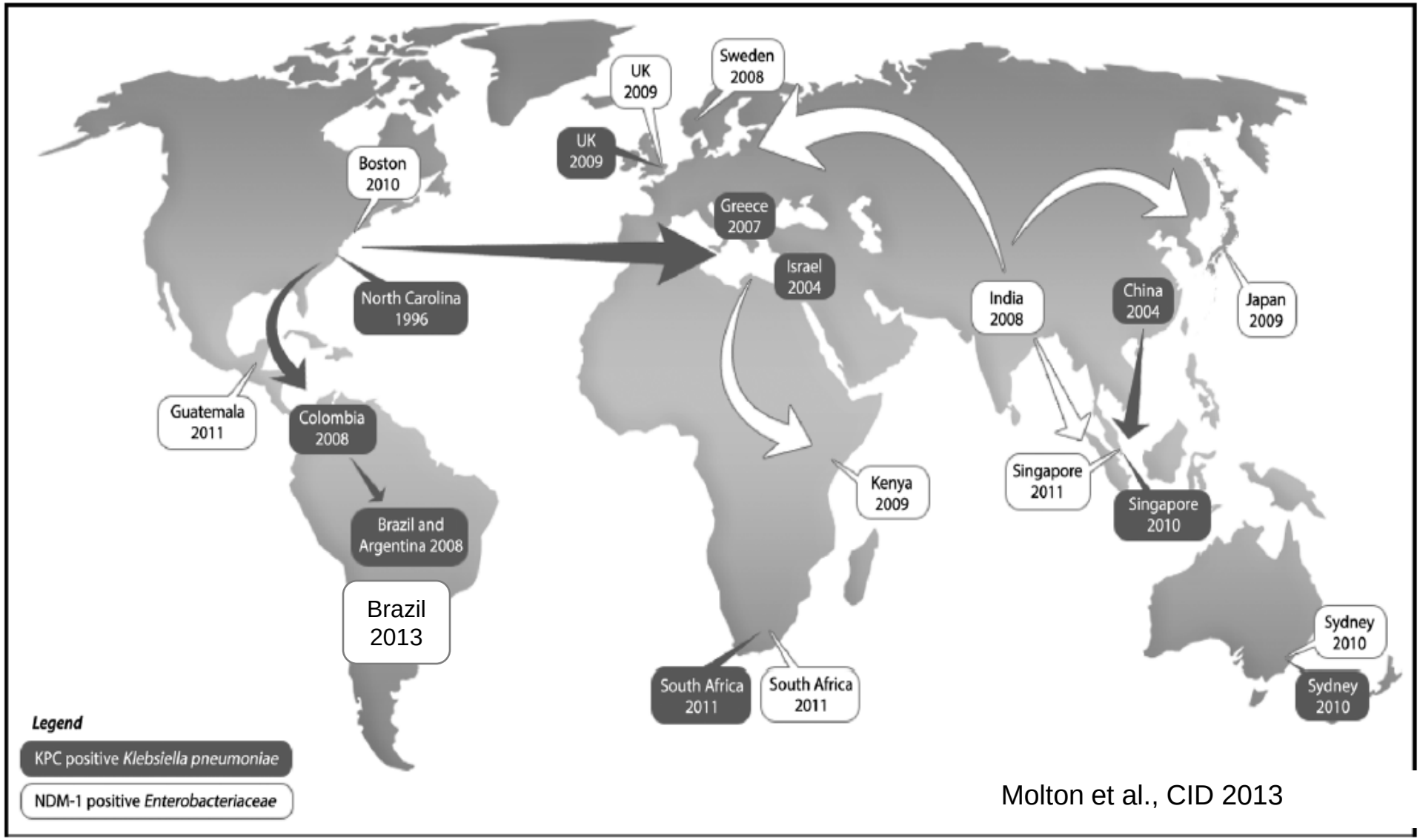
- **Ahmed-Bentley *et al*.**, Antimicrob Agents Chemother.
  - Outbreak in a Calgary Hospital
  - Index case with hospitalization Hx in India
  - Several MDR GNR organisms
  - Transmission to 5 patients was identified; resulted in death of 1 patient from sepsis

## *Notes from the Field*

New Delhi Metallo-β-Lactamase–Producing *Escherichia coli* Associated with Endoscopic Retrograde Cholangiopancreatography — Illinois, 2013


Transmission via medical devices
- reviewed cleaning and disinfection process
- no lapse in protocol

# NDM and KPC World-Wide




Molton et al., CID 2013

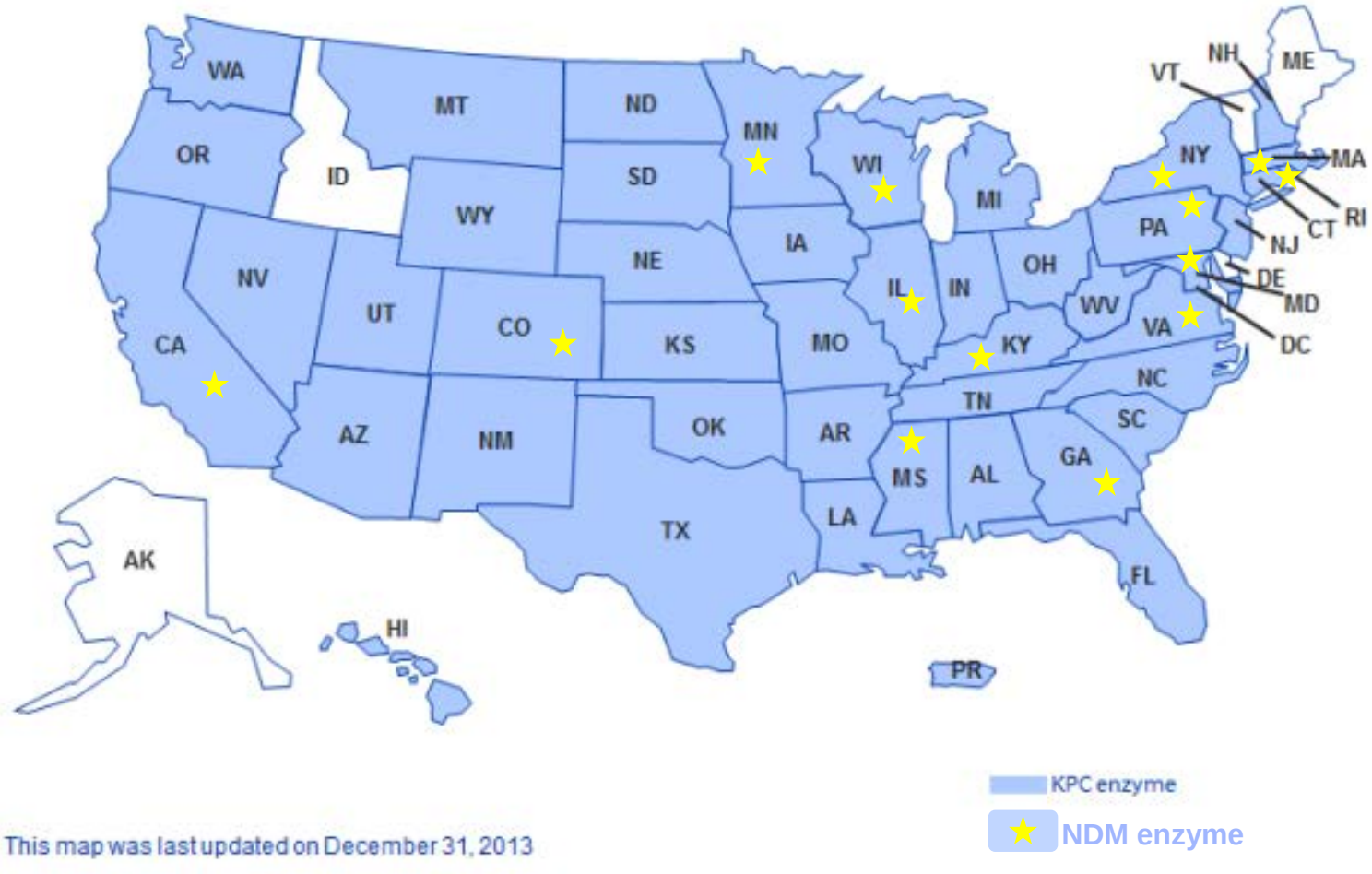
# Global Dissemination of KPC

- United States
  - KPC first reported in North Carolina in 2001-subsequent outbreaks and transmission of KPC-producing organisms reported in northeastern U.S
  - KPCs now in 42 states Dominant clone ST258 accounts for 70% of KPC isolates sent to CDC
  - KPC increased from 1.2% in 2001 to 4.2% in 2011
  - 2012, 4.6% of acute-care hospitals reported at least one CPE HAI

- Israel
  - Increased reports of KPC cases started in 2006
  - 8 hospitals and 5 long-term care centers with similar PFGE fingerprints
  - Genetic relation to U.S strains suggested strain exchange

MMWR Weekly 2013. 62(09);165-170. Gupta, N et al. 2011 CID.53:60-67.

# KPC and NDM in the USA






http://www.cdc.gov/hai/organisms/cre/TrackingCRE.html

# First introductions of KPC to Canada

- 1st report KPC in Ottawa (3 cases), 2008
  - 2 cases had travel history to USA
  - possible transmission

  Goldfarb et al. (2009) JCM 47:1920–1922
- KPC strains and plasmids similar between NYC and Toronto

  Mataseje et al, (2011) JAC 66:1273–1277

# KPC Outbreaks in Canada

1 case from Toronto in 2008, no travel history

Pillai et al, (2009) EID 15:827-828

**Outbreak 1**

- ICU 9 cases (3 pneumonia, 1 UTI, 1 SSI)
- *E. coli* (5), *K. oxytoca* (2), *S. marcescens* (2), and *C. freundii* (1)
- 4 deaths none attributed entirely to infection
  - 2012 Leung et al, Can J Infect Dis Med Micro

**Outbreak 2**

- 16 patients with KPC producing *Enterobacter cloacae*
- $bla_{KPC}$ localized on multiple plasmids in a diverse non-clonal genetic background of *E. cloacae*
  - 2013 Haraoui, J Clin Micro

**Now seeing outbreaks in Montreal**

J Antimicrob Chemother 2012; 67: 1597–1606
doi:10.1093/jac/dks121 Advance Access publication 11 April 2012

Journal of Antimicrobial Chemotherapy

# OXA-48-like carbapenemases: the phantom menace

Laurent Poirel*, Anaïs Potron and Patrice Nordmann

- First described in Turkey in 2004
  Poirel et al. 2004. AAC. 48:15–22
- Focused around Mediterranean countries
- Outbreak of OXA-48 *K. pneumoniae* in France in 2010. 10 ICU patients in 2 months. 5 died.
  Cuzon et al. AAC 2011. 55(5):2420-2423.
- Found in 2/4 “puddles” sampled in Morocco
  Potron et al. 2011. AAC 2011. 55:5413-4.
- Most difficult to detect of the carbapenemases
  - Low MICs to carbapenem and cephalosporins
  - Under reporting?

Diagnostic Microbiology and Infectious Disease 76 (2013) 399–400

Contents lists available at SciVerse ScienceDirect

Diagnostic Microbiology and Infectious Disease

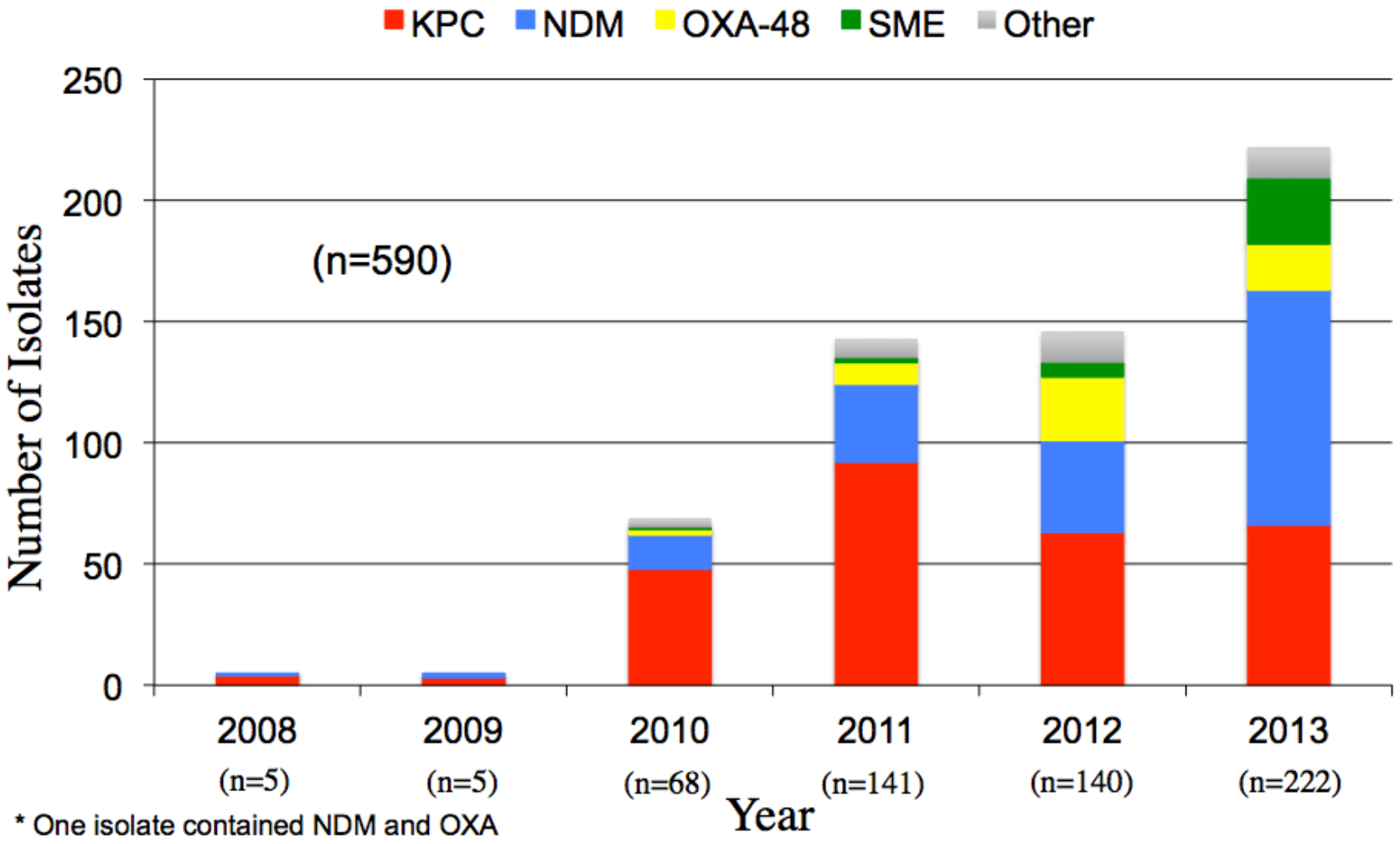
journal homepage: www.elsevier.com/locate/diagmicrobio

Letter

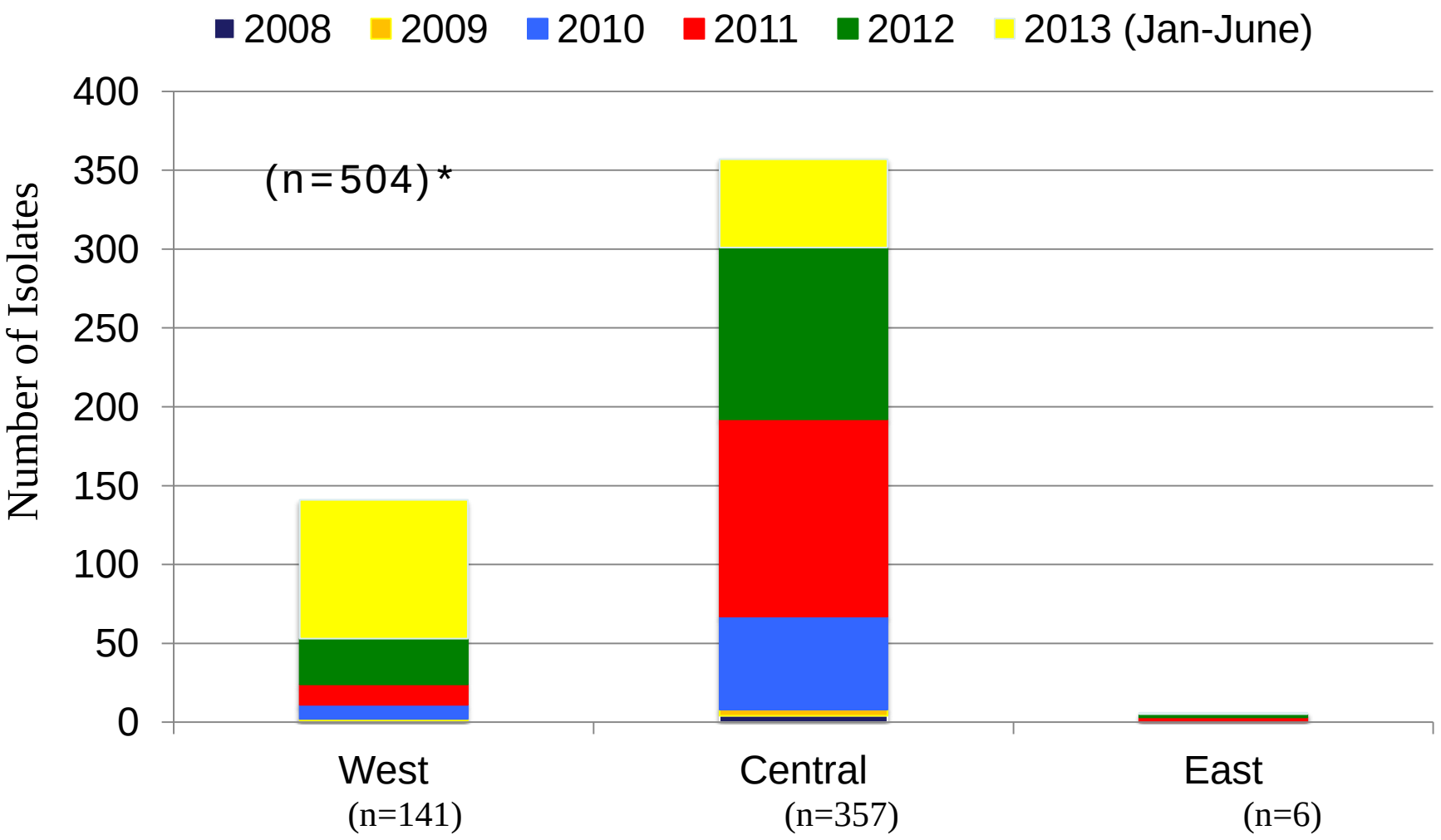
# OXA-48-like carbapenemase-producing Enterobacteriaceae in Ottawa, Canada☆

- 5 patients with healthcare outside of Canada
  - Syria, Egypt, St Lucia, Saudi Arabia, Australia and India
- No reports of outbreaks in Canada

# CPE in Canada: CPHLN Data

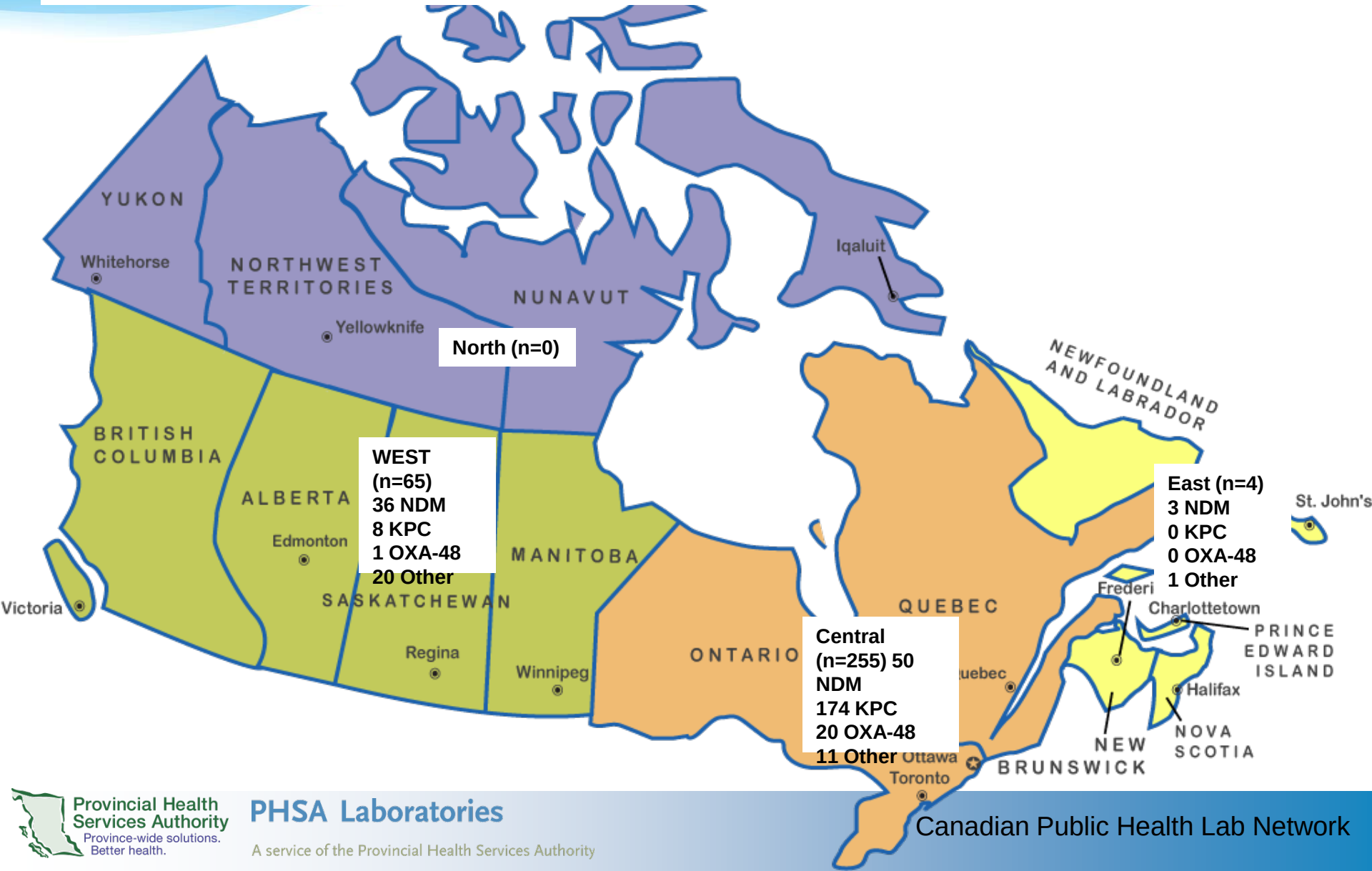


# CPE by Region in Canada: CPHLN Data




* One isolate contained NDM and OXA

# Enterobacteriaceae Producing Carbapenemases in Canada (n=324) As of August 31, 2012



# Treatment Options Enterobacteriaceae

- Carbapenems
  - e.g. Imipenem, Meropenem, etc
- ² -lactams (Ampicillin, Amoxicillin/Clavulanic, Cephalosporins)
- Fluoroquinolones
- Aminoglycosides
- Tetracyclines
- Nitrofurantoin

- Colistin
- Chloramphenicol
- Tigecycline

Kus et al CMAJ 2010

# Treatment Options for CPE

- ~~Carbapenems~~
  - ~~e.g. Imipenem, Meropenem, etc~~
- ~~$\beta$-lactams (Ampicillin, Amoxicillin/Clavulanic, Cephalosporins)~~
- ~~Fluoroquinolones~~
- ~~Aminoglycosides~~
- ~~Tetracyclines~~
- ~~Nitrofurantoin~~

- Colistin
- Chloramphenicol
- Tigecycline

Kus et al CMAJ 2010

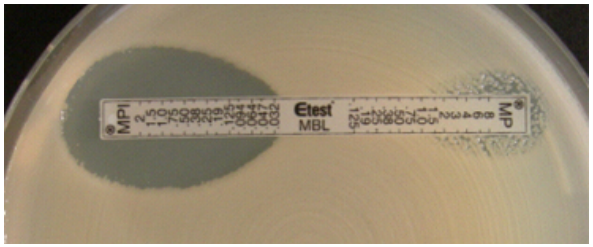
# BC's Response to this Emerging Pathogen

- **Collaboration for Surveillance in BC since 2010**
  - BC Public Health Microbiology and Reference Laboratory (PHMRL)
  - BC Association of Medical Microbiologists (BCAMM) and associated labs
  - National Microbiology Laboratory (NML)

- **PICNet**
  - Carbapenem-resistant Gram-negative Bacilli (CRGNB) ToolkitToolkit 2011 http://www.picnet.ca/education-training/67/carbapenem-resistant-gram-negative-bacilli-(crgnb)-toolkit

# Frontline Laboratories

- Patient screening program as appropriate to the patient population and risk factors
  - Returning travelers from endemic regions
  - Patients with healthcare exposures in endemic regions
  - In-hospital contacts to known cases
- Specimen isolate screening methods
  - Follow up all carbapenem intermediate or resistant isolates with additional phenotypic tests (e.g. Etests, ROSCO disc tests, MAST disc tests, etc)
  - Send all potential CPO's to BCCDC lab



# Laboratory surveillance in BC (cont'd)

## BC Public Health Lab

- Implemented molecular detection tools to confirm suspicious isolates
- Called positive results to submitting lab
  - travel history?
  - infection control interventions
- Repository for all identified isolates in BC
- Regular communications to update BC scenario via LabTrends http://www.bccdc.ca/PHSALaboratories/PublicationsandReports/default.htm

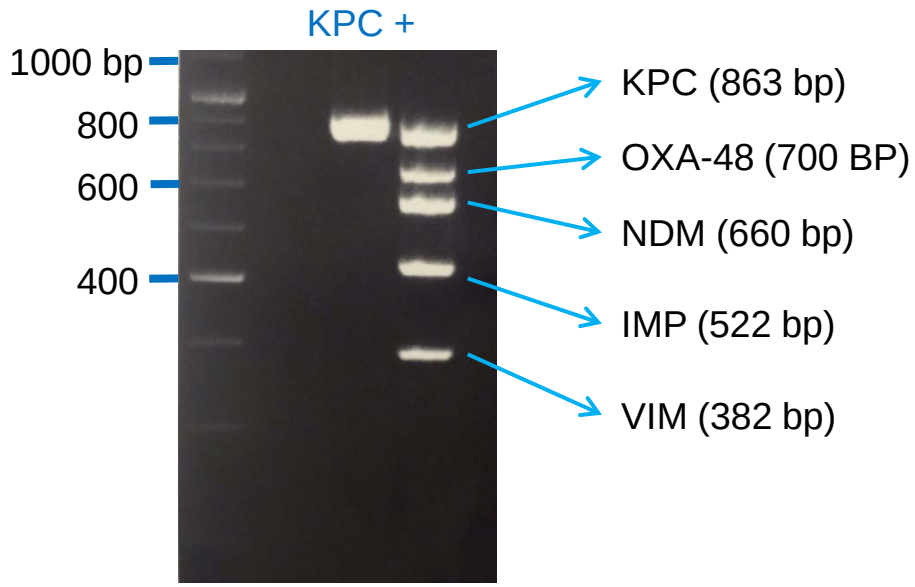
# Laboratory surveillance in BC

- Isolates submitted to BC Public Health Lab since Oct 2010 (2008 by collection date)
  - Carbapenem intermediate and resistant isolates
- Multiplex PCR (NML and Hanson *et al*)
  - CPO
    - KPC, NDM, IMP, VIM, OXA-48, (SME)
  - ESBL
    - SHV, TEM, CTX-M, OXA-1, CMY-2
  - AmpC
    - CMY/MOX, CMY-2/LAT, DHA, ACC, MIR/ACT, FOX

# CPE PCR at BC Public Health Lab

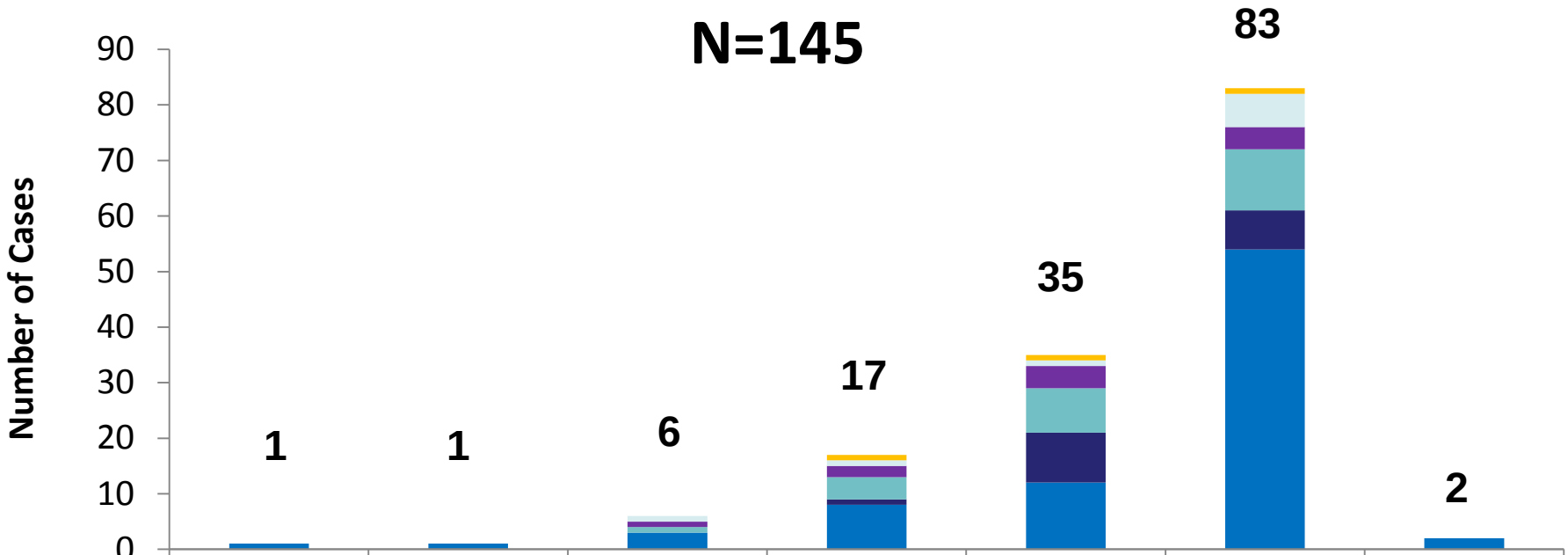
AMP-C panel

ESBL panel




>1000 isolates submitted to BCCDC from 2010 to December 2013 for testing.

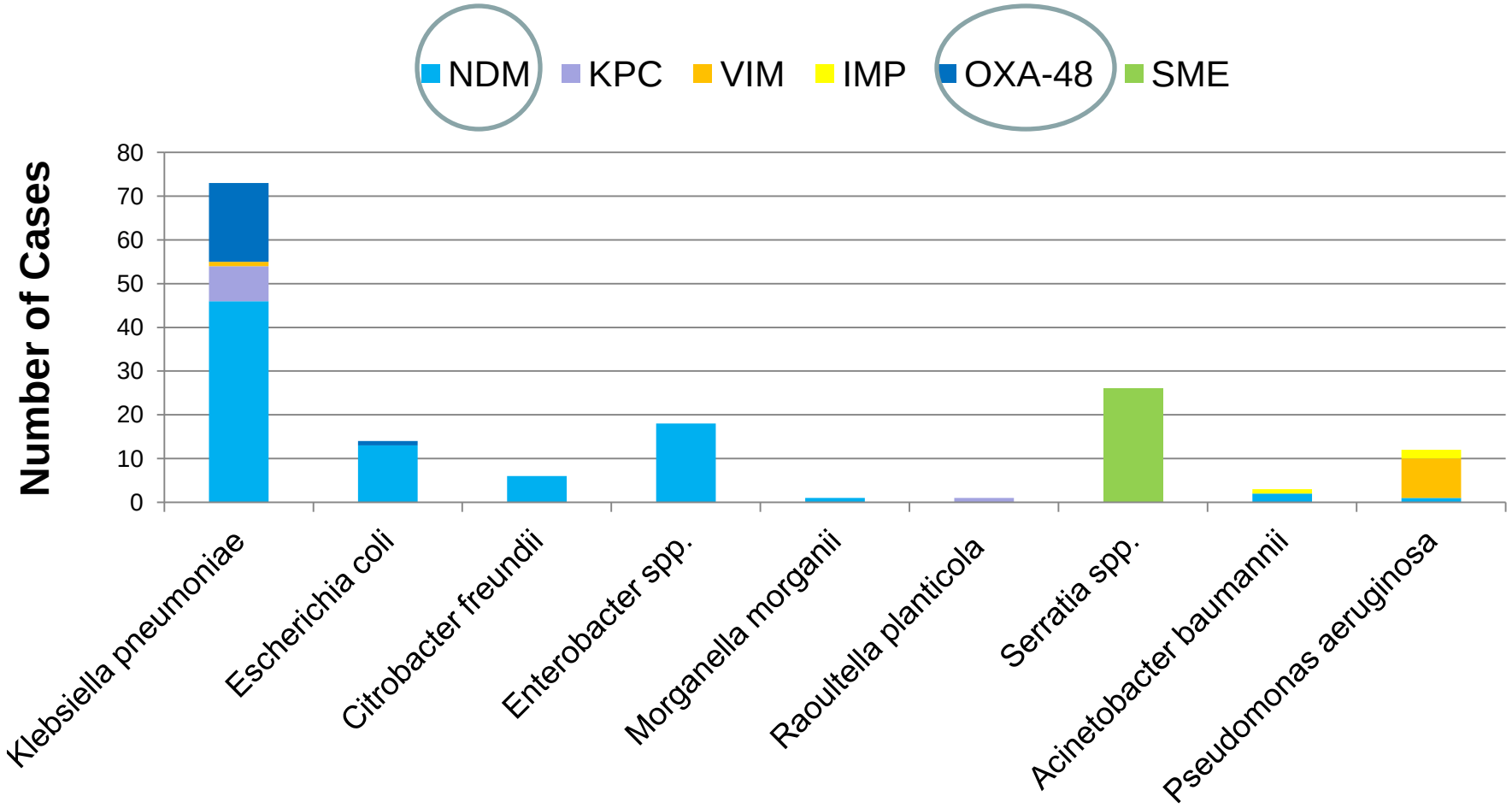
# All CPO, 2008-Current*
## N=145



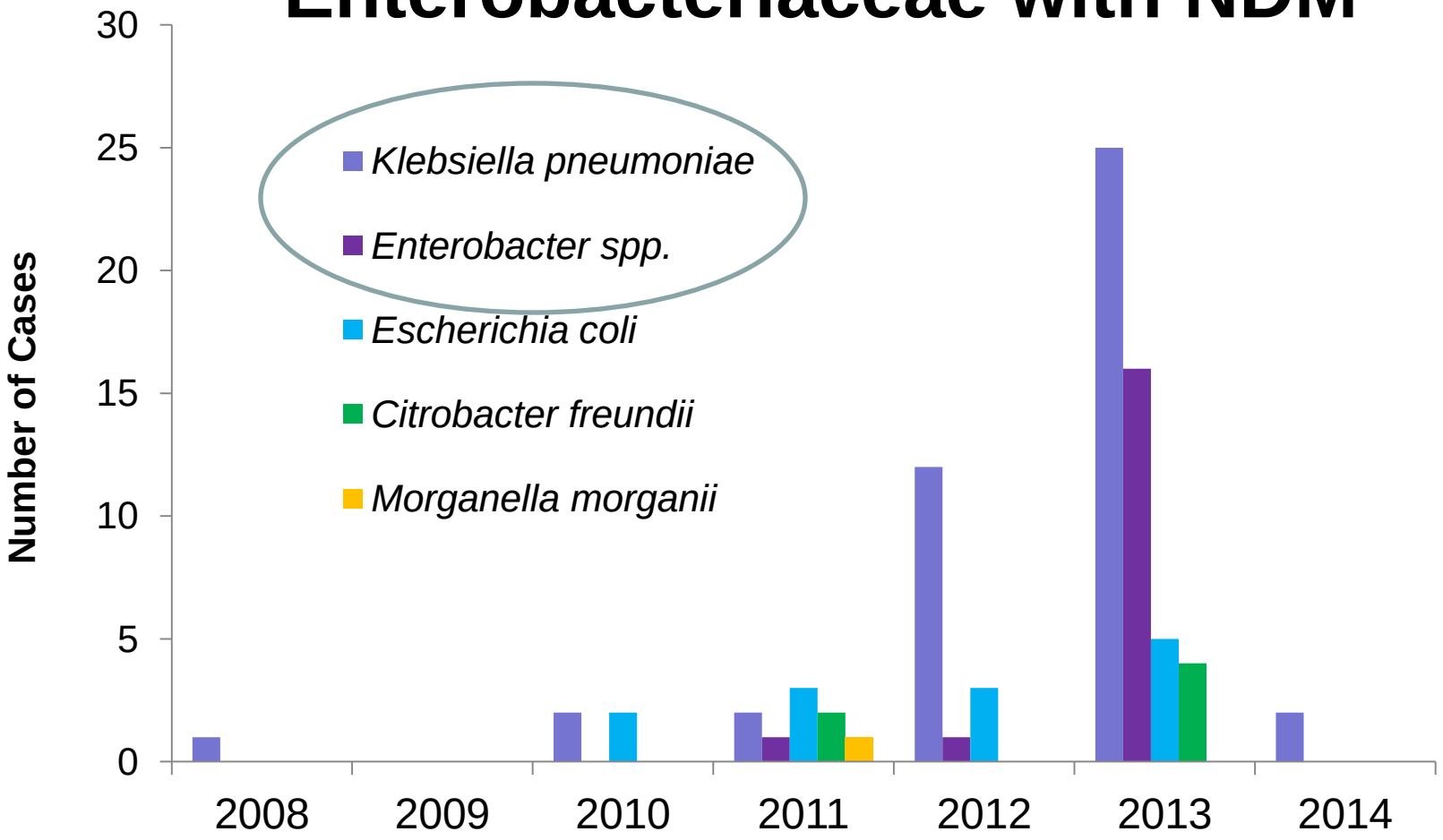

| | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|---|
| IMP (3) | | | | 1 | 1 | 1 | |
| KPC (9) | | | 1 | 1 | 1 | 6 | |
| VIM (11) | | | 1 | 2 | 4 | 4 | |
| SME (24) | | | 1 | 4 | 8 | 11 | |
| OXA-48 (17) | | | | 1 | 9 | 7 | |
| NDM (81) | 1 | 1 | 3 | 8 | 12 | 54 | 2 |

* Collection dates range from March, 2008-January 7, 2014.

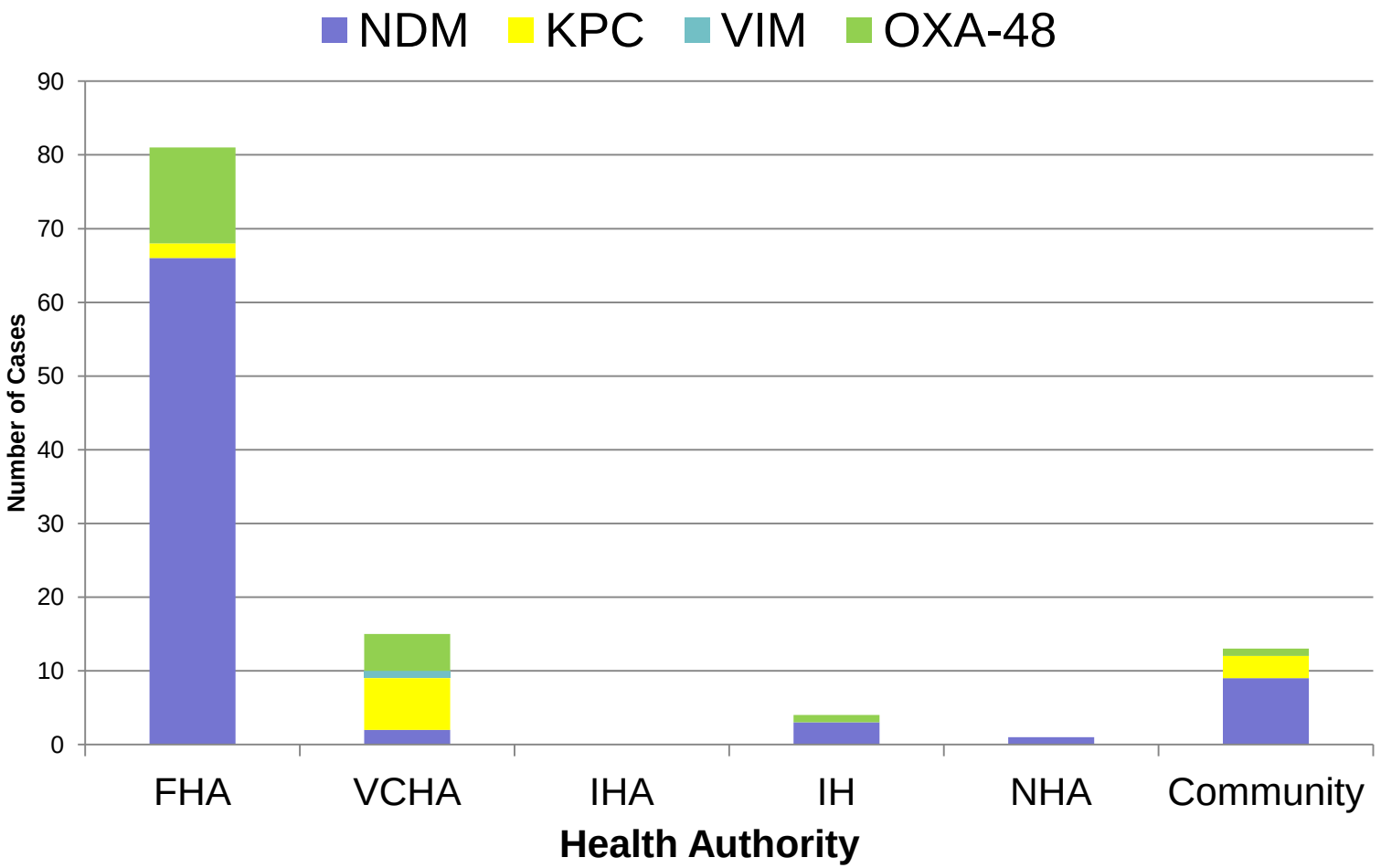
# Carbapenemase Producing Organisms by Species, 2008-Current*



# Enterobacteriaceae with NDM

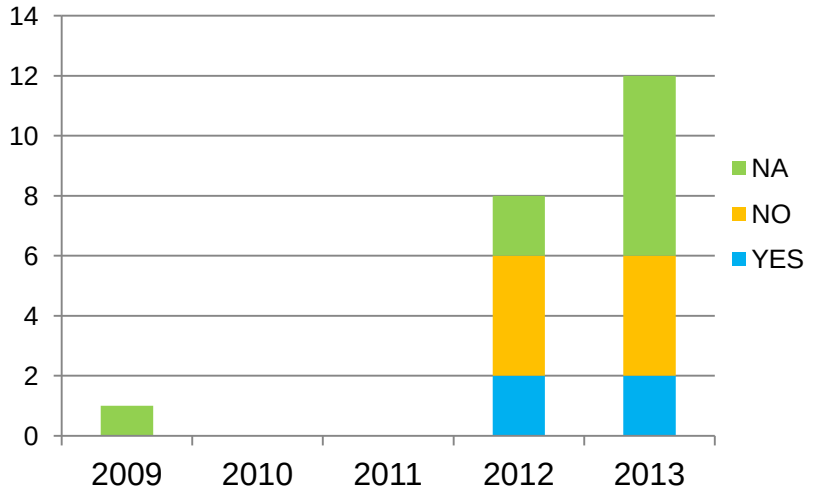


# CPE by Health Authority

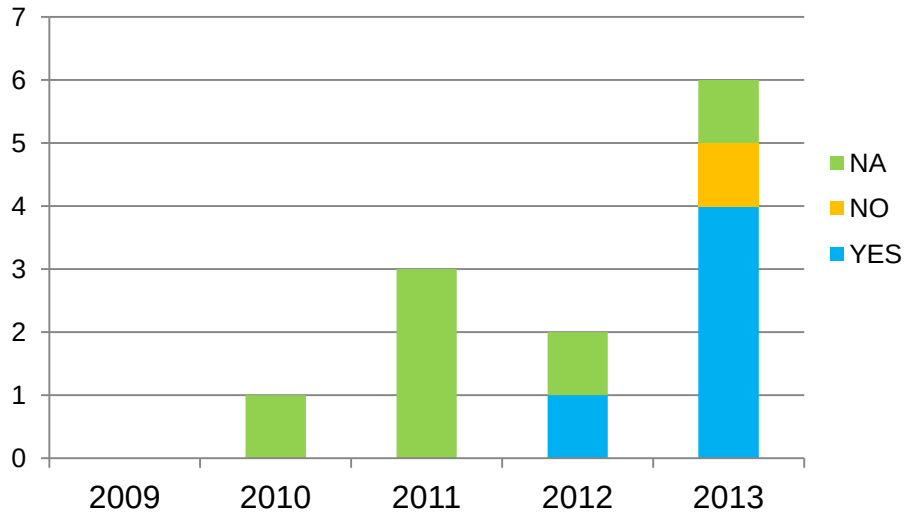


# NDM+ Cases with Travel History

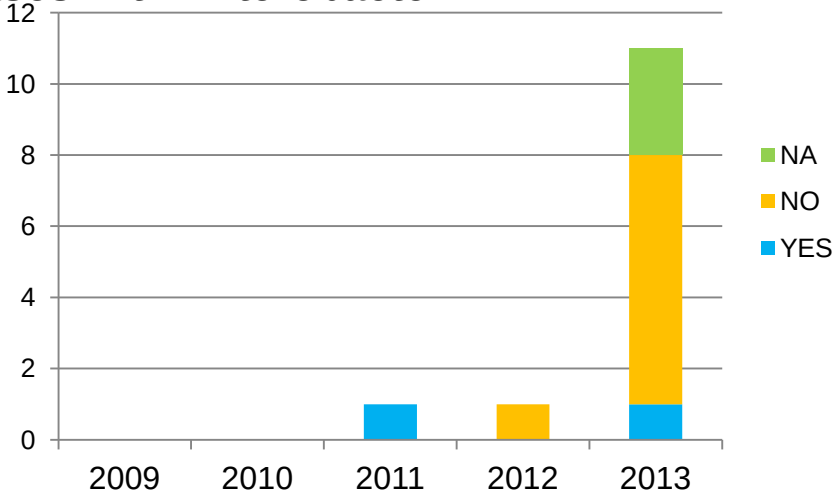
**Cases with *K. pneumoniae***




**Cases with *E.coli, Citrobacter* and *Acinetobacter***



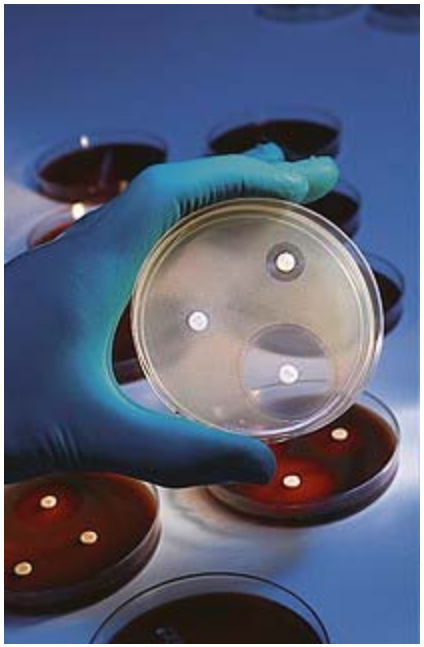

**Cases with Enterobacter**




- *K. pneumoniae and Enterobacter*
  - Combination of nosocomial transmission and travel related
- *E.coli, Citrobacter and Acinetobacter*
  - Mostly travel related

# 1) NDM: antibiogram comparisons

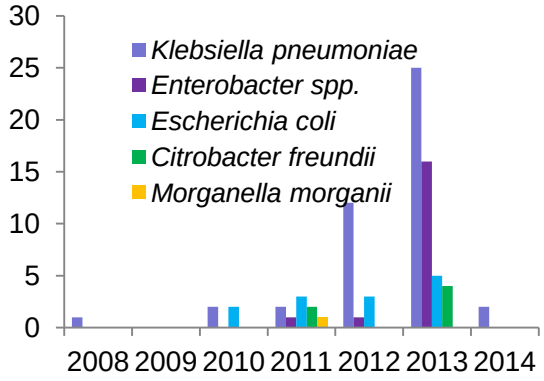
- Can the comparison of isolate antibiograms be predictive of “clonality”



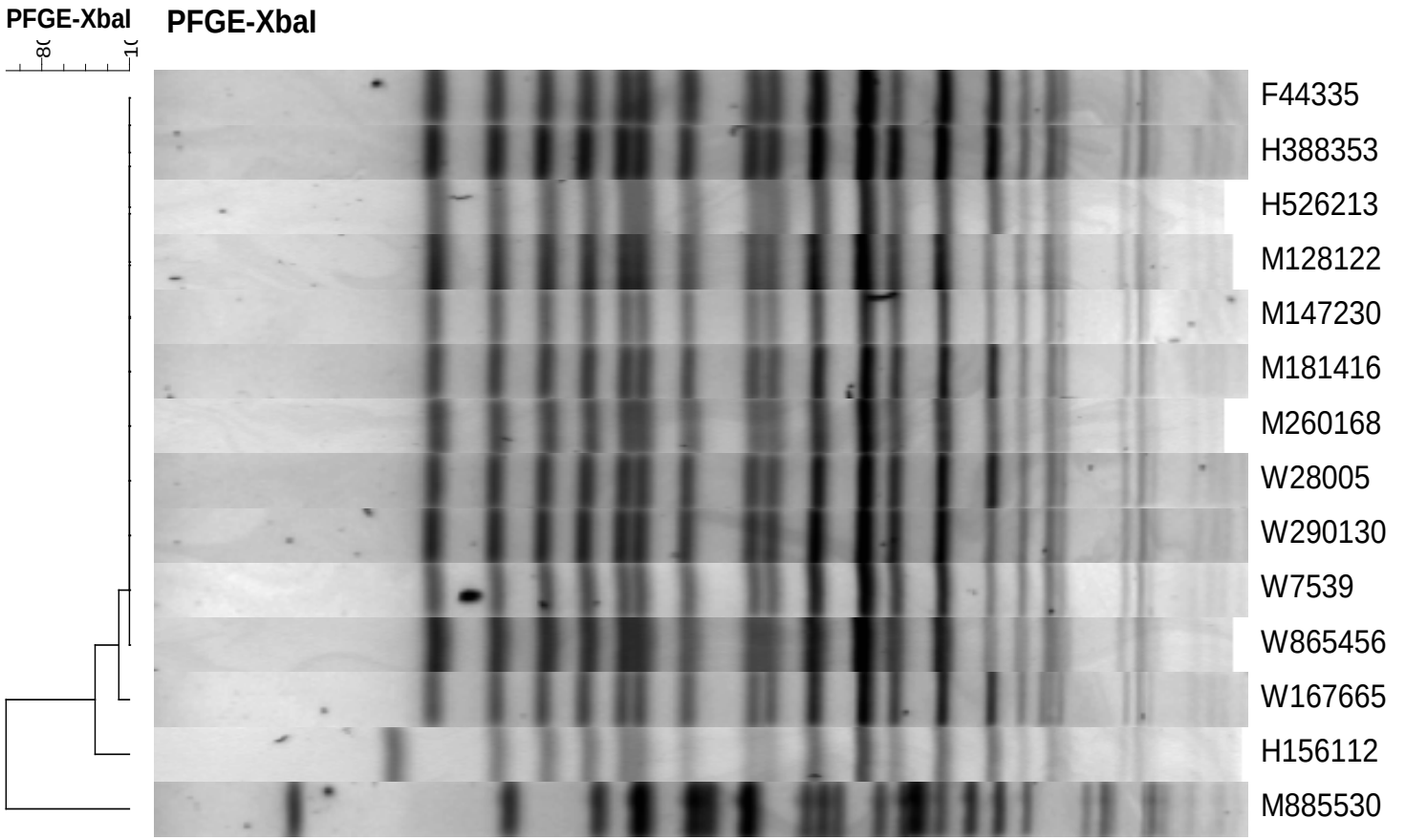
# 2) NDM: genotype comparison

- Can the presence of other resistance genes detected by PCR predictive of "clonality"?

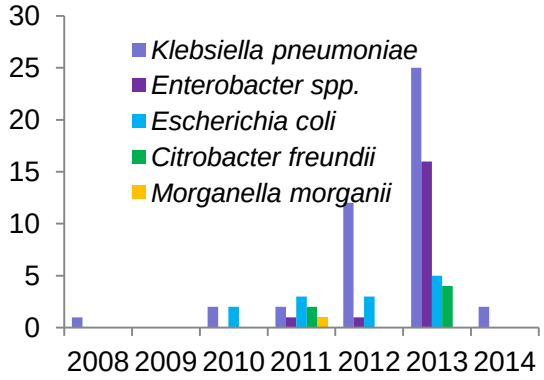
| KPC | NDM | IMP | VIM | SHV | TEM | CTX-M | OXA-1 | CMY-2 | CMY-1 | CMY-2/LAT | DHA | ACC | MIR/ACT | FOX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Neg | Pos | Neg | Neg | Neg | Pos | Pos | Pos | Neg | Neg | Neg | Pos | Neg | Neg | Neg |
| Neg | Pos | Neg | Neg | Neg | Pos | Pos | Pos | Neg | Neg | Neg | Pos | Neg | Neg | Neg |
| Neg | Pos | Neg | Neg | Neg | Pos | Pos | Pos | Neg | Neg | Neg | Pos | Neg | Neg | Neg |
| Neg | Pos | Neg | Neg | Neg | Pos | Pos | Pos | Neg | Neg | Neg | Pos | Neg | Neg | Neg |




# PFGE of *Enterobacter cloacae*



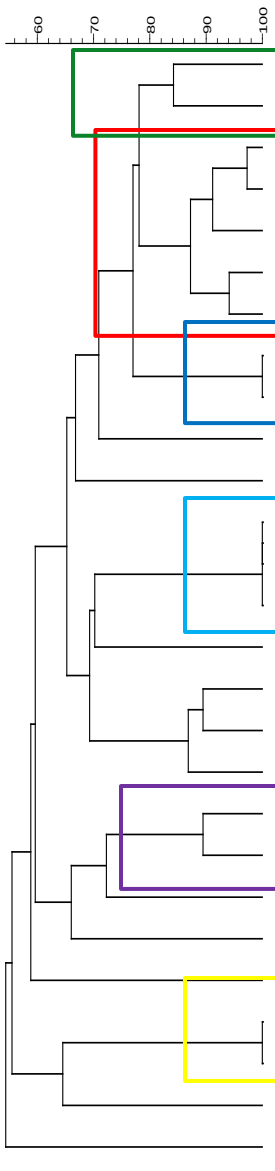

**Travel**




# *Enterobacter cloacae* genotype predicts clonality

| KPC | NDM | IMP | VIM | SHV | TEM | CTX-M | OXA-1 | CMY-2 | CMY-1 | CMY-2/LAT | DHA | ACC | MIR/ACT | FOX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Neg | Pos | Neg | Neg | Neg | Pos | Pos | Pos | Neg | Neg | Neg | Pos | Neg | Neg | Neg |
| Neg | Pos | Neg | Neg | Neg | Pos | Pos | Pos | Neg | Neg | Neg | Pos | Neg | Neg | Neg |
| Neg | Pos | Neg | Neg | Neg | Pos | Pos | Pos | Neg | Neg | Neg | Pos | Neg | Neg | Neg |
| Neg | Pos | Neg | Neg | Neg | Pos | Pos | Pos | Neg | Neg | Neg | Pos | Neg | Neg | Neg |

# PFGE of *K. pneumoniae*

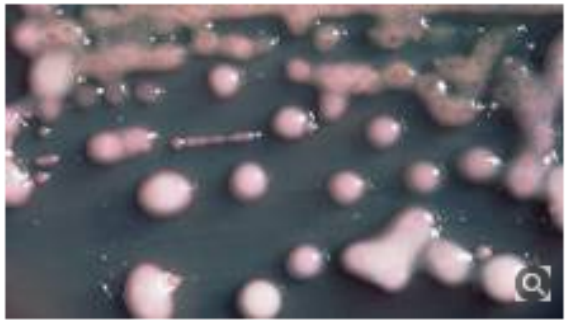



PFGE-XbaI

| Pt / Year | GN | GNTP ID? | AbG ID? | Trav | Hx |
|---|---|---|---|---|---|
| Pt 8 2011 | KPC | N | | Y | US, multip adm |
| Pt 8 2011 | KPC | | | | |
| Pt 9 2012 | NDM | | | Y | |
| Pt 38 2013 | NDM | | | N | |
| Pt 9 2011 | NDM | Y | Y | | |
| Pt 38 2013 | NDM | | | | |
| Pt 9 2011 | NDM | | | | |
| Pt 6 2011 | NDM | Y | N | Y | India, multip adm |
| Pt 6 2011 | NDM | | | | |
| Pt 32 2012 | KPC | | | | |
| Pt 35 2012 | NDM | | | | |
| Pt 23 2012 | NDM | | | | |
| Pt 20 2012 | NDM | N | N | | |
| Pt 18 2012 | NDM | | | | |
| Pt 3 2010 | NDM | | | | |
| Pt 22 2012 | NDM | N | | | |
| Pt 29 2012 | NDM | | | N | |
| Pt 39 2013 | NDM | | | | |
| Pt 2 2009 | NDM | Y | | Y | India |
| Pt 2 2008 | NDM | | | | |
| Pt 33 2012 | NDM | | | | |
| Pt 37 2013 | NDM | | | | |
| Pt 28 2012 | NDM | | | | |
| Pt 5 2010 | KPC, V | Y | | Y | Greece, hosp |
| Pt 5 2010 | KPC, V | | | | |
| Pt 30 2012 | NDM | | | | |
| Pt 7 2011 | NDM | | | | |

# Plasmid-mediated transmission

| Pt/ Year | Species | KPC | NDM | IMP | VIM | SHV | TEM | CTX-M | OXA-1 | CMY-2 | CMY-1 | CMY-2/LAT | DHA | ACC | MIR/ACT | FOX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pt 16, 2011 | *E. coli* | Neg | Pos | Neg | Neg | Neg | Neg | Pos | Pos | Pos | Neg | Pos | Neg | Neg | Neg | Neg |
| Pt 16, 2011 | *E. cloacae* | Neg | Pos | Neg | Neg | Pos | Pos | Pos | Pos | Neg | Neg | Neg | Neg | Neg | Neg | Neg |
| Pt 22, 2012 | *E. coli* | Neg | Pos | Neg | Neg | Neg | Pos | Pos | Pos | Neg | Neg | Neg | Neg | Neg | Neg | Neg |
| Pt 22, 2012 | *E. cloacae* | Neg | Pos | Neg | Neg | Neg | Pos | Pos | Pos | Neg | Neg | Neg | Neg | Neg | Neg | Neg |
| Pt 22, 2012 | *K. pneumoniae* | Neg | Pos | Neg | Neg | Pos | Pos | Neg | Neg | Neg | Neg | Neg | Neg | Neg | Neg | Neg |



# B.C. steps up battle with 'nightmare bacteria' cluster

WENDY STUECK

VANCOUVER — The Globe and Mail

Published Thursday, Jan. 23 2014, 9:00 AM EST

Last updated Friday, Jan. 24 2014, 9:31 PM EST

# How are these organisms transmitted?

1. Patient-to-patient
2. Shared Health Care equipment
3. Environmental Contact (environmental reservoirs)
4. Health care workers (Primarily hands)

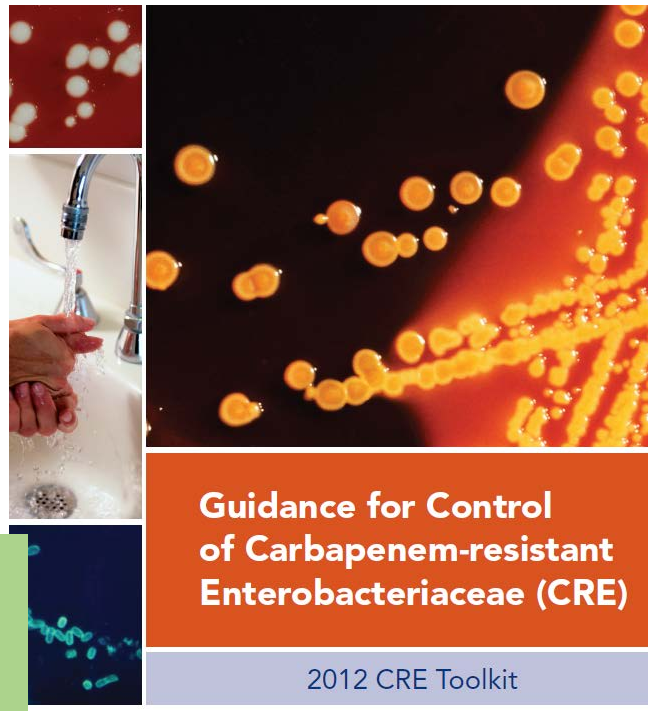
# How to prevent spread

MAJOR ARTICLE

Containment of a Country-wide Outbreak of Carbapenem-Resistant *Klebsiella pneumoniae* in Israeli Hospitals via a Nationally Implemented Intervention

Mitchell J. Schwaber,[1] Boaz Lev,[2] Avi Israeli,[2] Ester Solter,[1] Gill Smollan,[1] Bina Rubinovitch,[1] Itamar Shalit,[1] Yehuda Carmeli,[1] and the Israel Carbapenem-Resistant Enterobacteriaceae Working Group[a]

[1]National Center for Infection Control, Israel Ministry of Health, Tel Aviv, and [2]Israel Ministry of Health, Jerusalem, Israel



**Guidance for Control of Carbapenem-resistant Enterobacteriaceae (CRE)**

2012 CRE Toolkit

## Screening, Testing and Surveillance for Antibiotic-Resistant Organisms (AROs)

In All Health Care Settings

PICNet PROVINCIAL INFECTION CONTROL NETWORK OF BRITISH COLUMBIA

**Management of Carbapenem Resistant Gram-Negative Bacilli (CRGNB)**

Provincial Infectious Diseases Advisory Committee (PIDAC)

# Risk factors for Colonization and Infection with CPE

**Risk factors for acquisition of CPE**

- prolonged hospitalization
- Poor functional status
- ICU stay
- invasive devices
- Immunosuppresion
- multiple antibiotic agents

**Risk factors for infection once colonized with CPE**

- Previous invasive procedure
- Diabetes mellitus
- Solid organ tumor
- Tracheostomy
- Urinary catheter
- Prior exposure to antipseudomonal penicillin

If colonized with CPE, 9-47% of patients may develop infection

# CPE Measures Implemented at Affected Units

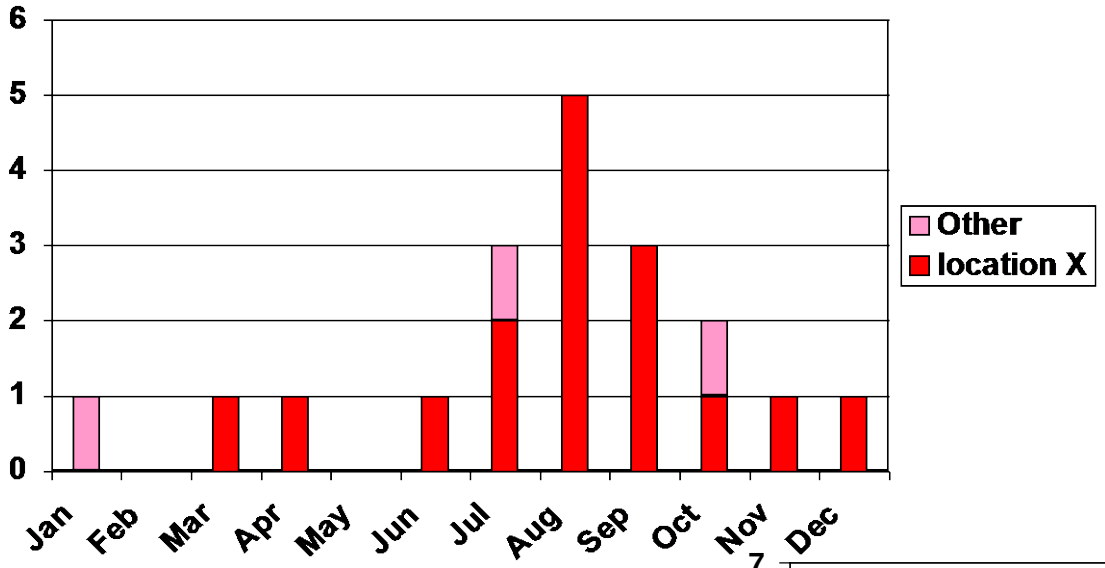
- Screening/Active surveillance
  - On admission to Unit
  - Weekly point prevalence
  - All contacts of suspect or confirmed cases, at 0, 7 and 21 days
- Precautions
  - Private room and staff cohorting and dedicated equipment
- Cohorting of patients and staff
  - “CPE” nursing assignments & dedicated ward
  - Hand hygiene & PPE (goal: 100%)
  - Weekly audits
- Antimicrobial stewardship

# CPE Measures Implemented at Affected Units (2)

- Avoid discarding any bodily fluids in sinks
- Cleaning
  - Enhanced cleaning including daily 2nd clean of high touch surfaces in affected rooms/units
  - Use hydrogen peroxide
  - Terminal clean on discharge of colonized patients:
    - Discard all supplies, terminal clean, audit of clean
- Daily CHG baths for all colonized patients.

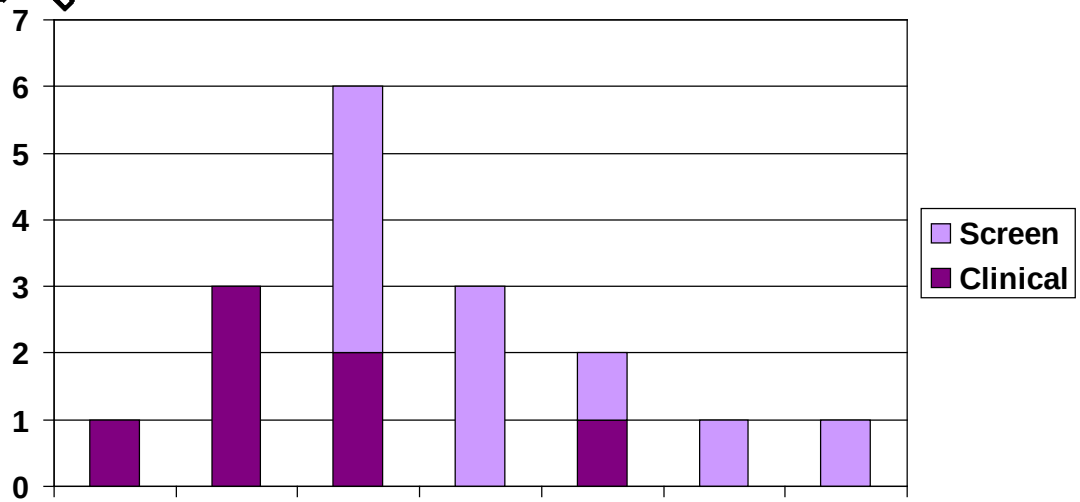
Courtesy of FHA

# NDM-positive Isolates from Location X in FHA facility 2013

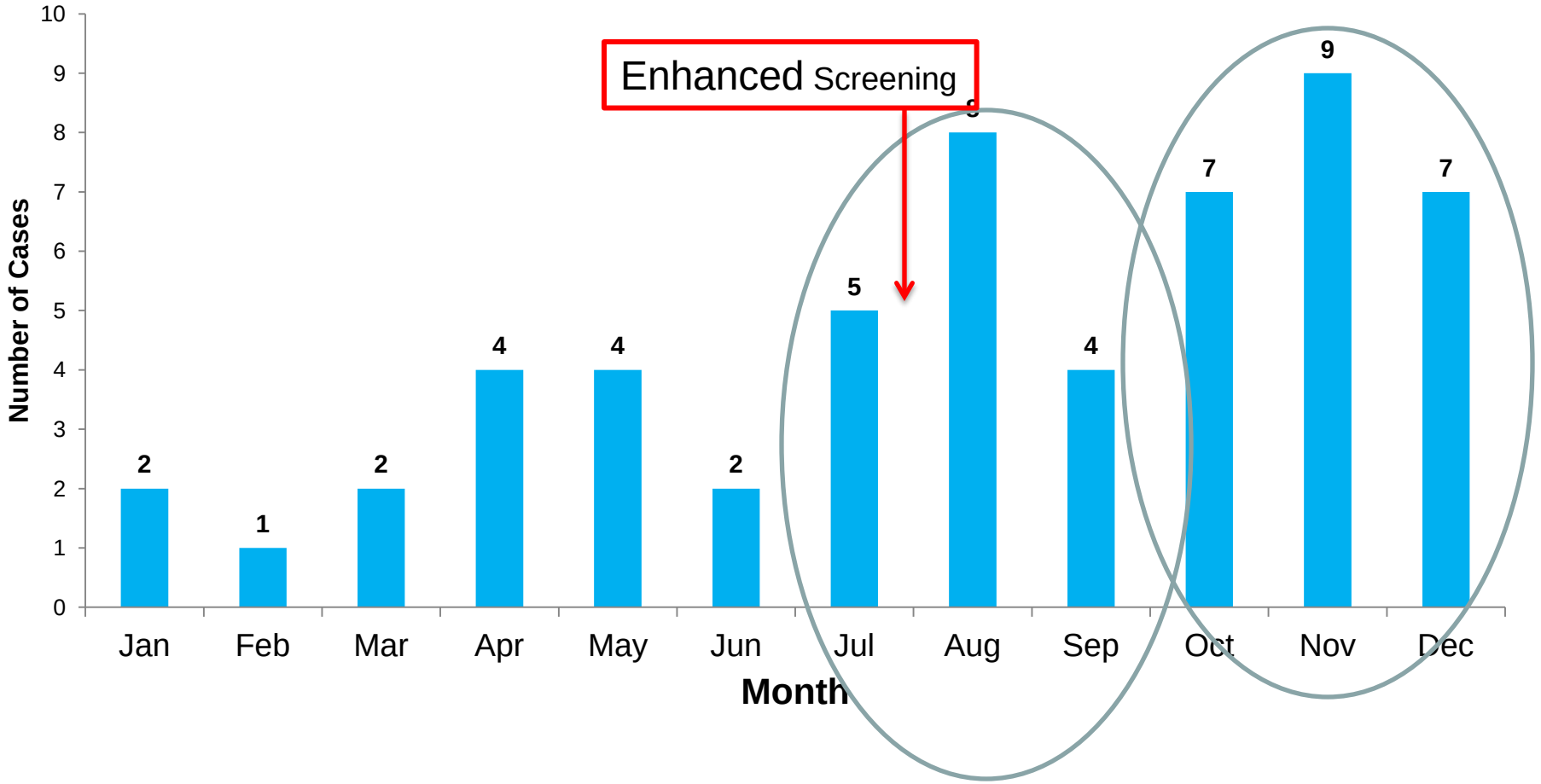



By Location

By Specimen Type



# Enterobacteriaceae with NDM in 2013 (Total=52)



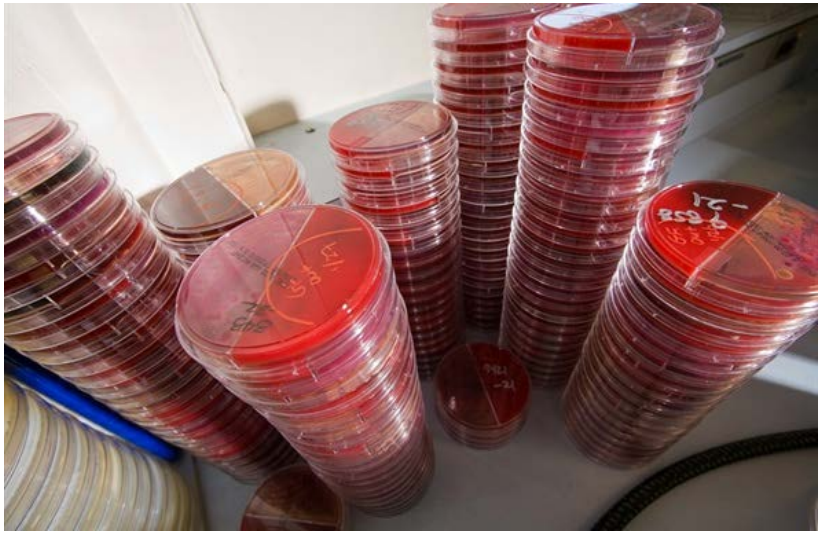
# Infection Control Processes "in the works"

- Region-wide screening for all admitted patients
  - Question: "Have you been hospitalized or had renal dialysis outside of Canada anytime in the previous 6 months?"
  - If yes: patient will have rectal screen for CPE
- Flagging of contacts who leave hospital before 21 days of CRE screening for screening on re-admission

# FHA CPE Activity

- No new cases since mid-January

- Increase specimen volume for the lab



# Next Steps and Challenges

- Better and faster testing
  - Develop Real-time PCR method for screening specimens directly
- Maintain aggressive infection control state & CPE alerts between facilities
- Continued Provincial level surveillance with infection control data
  - Collaboration with PICNet
- Further explore genomic characteristics of BC strains and transmission behaviour
  - Whole Genome Sequencing

# Summary

- CPE are an emerging pathogen with global spread, now in Canada
- CPE can spread within institutions
- The most vulnerable patients are the most at risk to become colonized and infected
- Treatment of infections is complex
- Control of spread requires full compliance with precautions and antibiotic stewardship

# Summary- BC specific

- CPE present in BC. Most commonly NDM and OXA-48
  - Most are identified in hospital setting
- CPE initially introduced to BC facilities from returning travelers to endemi2012: Evidence of nosocomial transmission in BC. Mostly due to NDM+ *K. pneumoniae* and *Enterobacter cloacae*
- Characterization of BC strains suggests clonal nature of *Enterobacter cloacae* spread, but also plasmid-mediated for *K. pneumoniae.*
- Use of “genotypic” patterns predictive of clonality for *Enterobacter cloacae*, but not for *K. pneumoniae*
- Clusters of CPE cases in facilities responding to enhanced screening and infection control interventions

# Acknowledgements

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Dr. Ben Mack

Dr. Dale Purych

Dr. Manal Tadros

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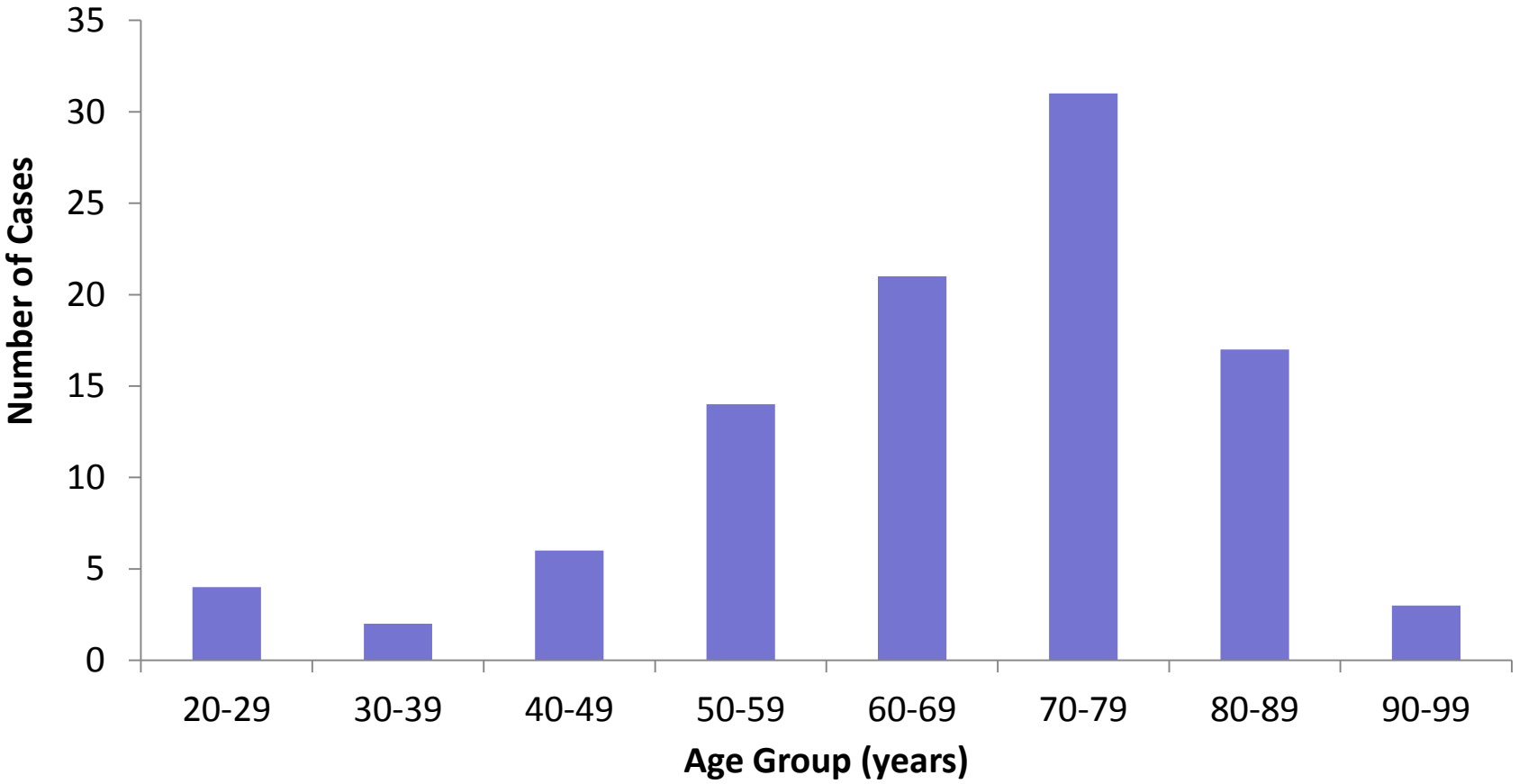
Dr. Michael Mulvey

# Thank you!

# Age Distribution for CPE



# Identified Organisms Harbouring NDM-1

- *E. coli* (ST131), *K. pneumoniae, K. oxytoca, C. freundii, E. cloacae, E. aerogenes, M. morganii*, *Proteus* spp., *Providencia* spp., and *Salmonella* Seftenberg
- *Achromobacter* spp
- *Aeromonas caviae*
- *Acinetobacter baumannii*
- *Kingella denitrificans*
- *Pseudomonas aeruginosa, P. putida, P. pseudoalcaligenes, P. oryzihabitans*
- *Stenotrophomonas maltophilia*
- *Sutonella indologenes*
- *Vibrio cholerae*
- *Shigella boydii*



Courtesy of Mike Mulvey, NML