

The application of syndromic surveillance to public health practice

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(Community Medicine and Clinical Epidemiology)

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STATEMENT OF ORIGINALITY

*The thesis contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. I give consent to the final version of my thesis being made available worldwide when deposited in the University's Digital Repository**, subject to the provisions of the Copyright Act 1968.*

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STATEMENT OF AUTHORSHIP

I hereby certify that the work embodied in this thesis contains a published paper/s/scholarly work of which I am a joint author. I have included as part of the thesis a written statement, endorsed by my supervisor, attesting to my contribution to the joint publication/s/scholarly work.

THESIS BY PUBLICATION

I hereby certify that this thesis is in the form of a series of published papers of which I am a joint author. I have included as part of the thesis a written statement from each co-author, endorsed by the Faculty Assistant Dean (Research Training), attesting to my contribution to the joint publications.

Beverley J Paterson

Date

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What an enjoyable and interesting journey this thesis has been. None of it would have been possible without my primary supervisor, Professor David Durrheim, who offered wisdom and calm advice – what an extraordinarily committed and knowledgeable person to have as a mentor. To Professor Cate D’Este who kept me on track over coffees at Estobar, many thanks for your insightful input.

To the Health Protection team at Hunter New England Health – what a professional and informed group of people you are to work with. A special thanks to Keith Eastwood and Tony Merritt for your great comments and advice.

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This research would not have been possible without the financial support of the Hunter Medical Research Institute, University of Newcastle, who allowed me the opportunity to undertake this PhD during my employment as a Research Fellow.

To Chris and Frances, big hugs – I think I’m finally there!

ABSTRACT

This *Thesis by Publication* is a series of eleven scientific papers and letters published in peer reviewed, professional journals which explore how syndromic surveillance has been applied to public health practice. At the time of submission, ten papers have been published in peer reviewed journals and one has been accepted for publication.

Chapter One, 'Overview', introduces the topic of syndromic surveillance. The separate papers are placed within the context of what is known about syndromic surveillance and public health.

Chapter Two, 'Literature Review', is a peer reviewed article '**The remarkable adaptability of syndromic surveillance to meet public health needs**' that examines the literature to determine how syndromic surveillance has been used as a tool in public health practice and how it has been adapted by practitioners over time to meet changing public health information needs. This scientific publication was published in the *Journal of Epidemiology and Global Health*.

Chapter Three, 'Gathering the evidence: syndromic data utilisation', includes four published papers and scientific letters that demonstrate how syndromic data sources can inform public health responses or provide additional information to help characterise a particular disease. The peer reviewed article '**Historical data and modern methods reveal insights in measles epidemiology: a retrospective closed cohort study**' was published in the journal *BMJ Open*. The scientific letter '**Influenza: H1N1 goes to school**' was published in the journal *Science*. The scientific letter '**Use of workplace absenteeism surveillance data for outbreak detection**' was published in the journal *Emerging Infectious Diseases*. The peer reviewed article '**Changes in the severity of 2009 pandemic A/H1N1 influenza in England: a Bayesian evidence synthesis**' was published in the *British Medical Journal*.

Chapter Four, 'Implementing and evaluating the evidence: syndromic surveillance in practice', is a series of three published papers and scientific letters that establish the value and effectiveness of developing a syndromic surveillance system for a specific purpose. The peer reviewed article '**Pacific-wide simplified syndromic surveillance for early warning of outbreaks**' was published in the journal *Global Public Health*. The peer reviewed article '**Sustaining surveillance: evaluating syndromic surveillance in the Pacific**' was published in *Global Public Health*. The scientific letter '**Pandemic response in low-resource settings**

requires effective syndromic surveillance' was published in the journal *Influenza and other respiratory viruses*.

Chapter Five, 'Presenting the evidence: changing public health policy', includes two published papers and one published scientific letter which illustrate how syndromic surveillance can be used to inform public health policy. The peer reviewed article '**A review of the epidemiology and surveillance of viral zoonotic encephalitis and the impact on human health in Australia**' has been published in the journal *New South Wales Public Health Bulletin*. The peer reviewed article '**Review of Australia's polio surveillance**' has been accepted for publication in the journal *Communicable Disease Intelligence*. The scientific letter, '**Guillain-Barré Syndrome**' has been published in the *New England Journal of Medicine*.

The final chapter, 'Discussion and Conclusions', summarises the overall findings from the thesis, discusses public health outcomes resulting from the thesis, identifies gaps in the literature and limitations of the research, and discusses further areas for research.

As demonstrated throughout the thesis, syndromic surveillance is a broad term covering multiple divergent approaches to surveillance. This flexibility appears to be its strength, making it useful to address a range of public health needs.

LIST OF CITATIONS FOR PAPERS INCLUDED IN THIS THESIS

1. **Paterson BJ**, Durrheim DN: The remarkable adaptability of syndromic surveillance to meet public health needs. *Journal of Epidemiology and Global Health* 2013, 3(1):41-47
2. **Paterson BJ**, Kirk MD, Cameron AS, D'Este C, Durrheim DN: Historical data and modern methods reveal insights in measles epidemiology: a retrospective closed cohort study. *BMJ Open* 2013, 3(1):doi:10.1136/bmjopen-2012-002033.
3. **Paterson B**, Durrheim DN, Tuyl F: Influenza: H1N1 goes to school. *Science* 2009, 325(5944):1071-1072.
4. **Paterson B**, Caddis R, Durrheim D: Use of workplace absenteeism surveillance data for outbreak detection. *Emerging Infectious Diseases* 2011, 17(10):1963-1964.
5. Presanis AM, Pebody RG, **Paterson BJ**, Tom BD, Birrell PJ, Charlett A, Lipsitch M, De Angelis D: Changes in severity of 2009 pandemic A/H1N1 influenza in England: a Bayesian evidence synthesis. *British Medical Journal* 2011, 343:d5408.
6. Kool JL, **Paterson B**, Pavlin BI, Durrheim D, Musto J, Kolbe A: Pacific-wide simplified syndromic surveillance for early warning of outbreaks. *Global Public Health* 2012, 7(7):670-681.
7. **Paterson BJ**, Kool JL, Durrheim DN, Pavlin B: Sustaining surveillance: evaluating syndromic surveillance in the Pacific. *Global Public Health* 2012, 7(7):682-694.
8. **Paterson BJ**, Durrheim DN, Hardie K. Pandemic response in low-resource settings requires effective syndromic surveillance. *Influenza and other respiratory viruses* 2013, doi 10.1111/irv.12098.
9. **Paterson BJ**, Mackenzie JS, Durrheim DN, Smith D: A review of the epidemiology and surveillance of viral zoonotic encephalitis and the impact on human health in Australia. *New South Wales Public Health Bulletin* 2011, 22(5-6):99-104.
10. **Paterson BJ**, Durrheim DN. Review of Australia's polio surveillance. *Communicable Disease Intelligence* (accepted for publication)
11. **Paterson BJ**, Durrheim DN: Guillain-Barre syndrome. *New England Journal of Medicine* 2012, 367(10):973.

STATEMENT OF CONTRIBUTION

1. **Paterson BJ**, Durrheim DN: The remarkable adaptability of syndromic surveillance to meet public health needs. *Journal of Epidemiology and Global Health* 2013, <http://dx.doi.org/10.1016/j.jegh.2012.12.005>.

I was the primary author on this scientific publication. I developed the concept, completed the literature review, undertook the analysis using NVivo, prepared and revised the manuscript, and submitted the manuscript for publication. I completed these activities in collaboration with DN. Durrheim.

2. **Paterson BJ**, Kirk MD, Cameron AS, D'Este C, Durrheim DN: Historical data and modern methods reveal insights in measles epidemiology: a retrospective closed cohort study. *BMJ Open* 2013, 3(1):doi:10.1136/bmjopen-2012-002033.

I was the primary author on this scientific publication. I developed the concept, designed the study, undertook the data collection in Canberra, Sydney and Adelaide, undertook the analysis and modelled the data, undertook the literature review, prepared and revised the manuscript, and submitted the manuscript for publication. These activities were undertaken in collaboration with Kirk MD, Cameron AS, D'Este C and Durrheim DN.

3. **Paterson B**, Durrheim DN, Tuyl F: Influenza: H1N1 goes to school. *Science* 2009, 325(5944):1071-1072.

I was the primary author on this scientific publication. In collaboration with Durrheim DN and Tuyl F, I developed the concept, undertook the data collection, completed the secondary analysis and modelled the data, prepared and revised the manuscript, and submitted the manuscript for publication.

4. **Paterson B**, Caddis R, Durrheim D: Use of workplace absenteeism surveillance data for outbreak detection. *Emerging Infectious Diseases* 2011, 17(10):1963-1964.

I was the primary author on this scientific publication. I developed the concept, undertook the data analysis, prepared and revised the manuscript, and submitted the manuscript for publication. These activities were undertaken in collaboration with Caddis R and Durrheim D.

5. Presanis AM, Pebody RG, **Paterson BJ**, Tom BD, Birrell PJ, Charlett A, Lipsitch M, De Angelis D: Changes in severity of 2009 pandemic A/H1N1 influenza in England: a Bayesian evidence synthesis. *British Medical Journal* 2011, 343:d5408.

I was the third author on this scientific publication. In collaboration with Presanis AM, Pebody RG, Tom BD, Birrell PJ, Charlett A, Lipsitch M and De Angelis D, I was involved in the data collection, interpretation of the data, contributed to model development and the preparation and revision of the manuscript.

6. Kool JL, **Paterson B**, Pavlin BI, Durrheim D, Musto J, Kolbe A: Pacific-wide simplified syndromic surveillance for early warning of outbreaks. *Global Public Health* 2012, 7(7):670-681.

I was the second author on this scientific publication. In collaboration with Kool JL, Pavlin BI, Durrheim D, Musto J and Kolbe A, I was involved in development of the concept, data collection and analysis, and prepared and revised the manuscript.

7. **Paterson BJ**, Kool JL, Durrheim DN, Pavlin B: Sustaining surveillance: evaluating syndromic surveillance in the Pacific. *Global Public Health* 2012, 7(7):682-694.

I was the primary author on this scientific publication. I designed the evaluation, prepared the interview guides, undertook the data collection (both in-country and through other methods) transcribed the interviews, undertook the data analysis, wrote and revised the manuscript, and submitted the manuscript for publication. These activities were undertaken in collaboration with Kool JL, Durrheim DN and Pavlin B.

8. Paterson BJ, Durrheim DN, Hardie K: **Pandemic response in low-resource settings requires effective syndromic surveillance**. *Influenza and Other Respiratory Viruses* 2013, doi 10.1111/irv.12098.

I was the primary author on this scientific publication. I developed the concept, prepared and revised the manuscript, and submitted the manuscript for publication. I undertook these in collaboration with Durrheim DN and Hardie K.

9. **Paterson BJ**, Mackenzie JS, Durrheim DN, Smith D: A review of the epidemiology and surveillance of viral zoonotic encephalitis and the impact on human health in Australia. *New South Wales Public Health Bulletin* 2011, 22(5-6):99-104.

I was the primary author on this scientific publication. In collaboration with Mackenzie JS, Durrheim DN and Smith D, I developed the concept, prepared and revised the manuscript, and submitted the manuscript for publication.

10. **Paterson BJ**, Durrheim DN. Review of Australia's polio surveillance. *Communicable Disease Intelligence* (accepted for publication)

I was the primary author on this scientific publication. I developed the concept, designed the study, prepared the interview guides, undertook the interviews (both face-to-face and telephone), completed the data analysis, presented the data to the *National Certification Committee for the eradication of polio* for validation, prepared and revised the manuscript, and submitted the manuscript for publication. I undertook this in collaboration with Durrheim DN.

11. **Paterson BJ**, Durrheim DN: Guillain-Barre syndrome. *New England Journal of Medicine* 2012, 367(10):973.

I was the primary author on this scientific publication. In collaboration with Durrheim DN, I developed the concept, prepared and revised the manuscript, and submitted the manuscript for publication.

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I, Paul Birrell, attest that Research Higher Degree candidate Beverley Paterson contributed substantially – in terms of data collection, contribution to model development and revision of the manuscript – to the publication:

Presanis AM, Pebody RG, Paterson BJ, Tom BD, Birrell PJ, Charlett A, Lipsitch M, De Angelis D:
Changes in severity of 2009 pandemic A/H1N1 influenza in England: a Bayesian evidence synthesis.
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Changes in severity of 2009 pandemic A/H1N1 influenza in England: a Bayesian evidence synthesis.
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Presanis AM, Pebody RG, Paterson BJ, Tom BD, Birrell PJ, Charlett A, Lipsitch M, De Angelis D:
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BMJ 2011, **343**:d5408.

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Kool JL, Paterson B, Pavlin BI, Durrheim D, Musto J, Kolbe A. **Pacific-wide simplified syndromic surveillance for early warning of outbreaks.** *Global Public Health* 2012, **7**(7):670-81.

Paterson BJ, Kool JL, Durrheim DN, Pavlin B: **Sustaining surveillance: evaluating syndromic surveillance in the Pacific.** *Global Public Health* 2012, **7**(7):682-694.

Paterson BJ, Kirk MD, Cameron AS, D'Este C, Durrheim DN: **Historical data and modern methods reveal insights in measles epidemiology: a retrospective closed cohort study.** *BMJ Open* 2013, **3**(1).

Paterson BJ, Mackenzie JS, Durrheim DN, Smith D: **A review of the epidemiology and surveillance of viral zoonotic encephalitis and the impact on human health in Australia.** *NSW Public Health Bulletin* 2011, **22**(5-6):99-104.

Paterson B, Durrheim DN, Tuyl F: **Influenza: H1N1 goes to school.** *Science* 2009, **325**(5944):1071-1072.

Paterson B, Caddis R, Durrheim D: **Use of workplace absenteeism surveillance data for outbreak detection.** *Emerging Infectious Diseases* 2011, **17**(10):1963-1964.

Paterson BJ, Durrheim DN: **Guillain-Barre syndrome.** *New England Journal of Medicine* 2012, **367**(10):973.

Paterson BJ, Durrheim DN: **The remarkable adaptability of syndromic surveillance to meet public health needs.** *Journal of Epidemiology and Global Health* 2013, **3**(1):41-47

Paterson BJ, Durrheim DN, Hardie K. **Pandemic response in low-resource settings requires effective syndromic surveillance.** *Influenza and other respiratory viruses* 2013, doi 10.1111/irv.12098.

Paterson BJ, Durrheim DN. **Polio surveillance review.** *Communicable Disease Intelligence* (accepted for publication)

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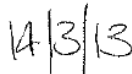
Statement of Contribution

I, Kate Hardie, attest that Research Higher Degree candidate Beverley Paterson contributed substantially – in terms of study concept and design, preparation and revision of the manuscript – to the publication:

Paterson BJ, Durrheim DN, Hardie K: **Pandemic response in low-resource settings requires effective syndromic surveillance**. Influenza Other Respi Viruses, 2013. doi: 10.1111/irv.12098. [Epub ahead of print]



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Paterson BJ, Kirk MD, Cameron AS, D'Este C, Durrheim DN: **Historical data and modern methods reveal insights in measles epidemiology: a retrospective closed cohort study.** *BMJ Open* 2013, **3**(1).



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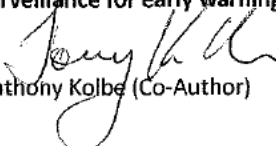
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Kool JL, Paterson B, Pavlin BI, Durrheim D, Musto J, Kolbe A. **Pacific-wide simplified syndromic surveillance for early warning of outbreaks**. Glob Public Health. 2012;7(7):670-81.


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and

Paterson BJ, Kool JL, Durrheim DN, Pavlin B: **Sustaining surveillance: evaluating syndromic surveillance in the Pacific.** *Glob Public Health* 2012, **7**(7):682-694.

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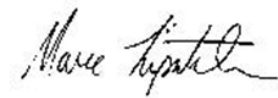
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I, Mark Lipsitch, attest that Research Higher Degree candidate Beverley Paterson contributed substantially – in terms of data collection, contribution to model development and revision of the manuscript – to the publication:

Presanis AM, Pebody RG, Paterson BJ, Tom BD, Birrell PJ, Charlett A, Lipsitch M, De Angelis D:
Changes in severity of 2009 pandemic A/H1N1 influenza in England: a Bayesian evidence synthesis.
BMJ 2011, **343**:d5408.

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Statement of Contribution

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Paterson BJ, Mackenzie JS, Durrheim DN, Smith D: **A review of the epidemiology and surveillance of viral zoonotic encephalitis and the impact on human health in Australia.** *N S W Public Health Bull* 2011, **22**(5-6):99-104.


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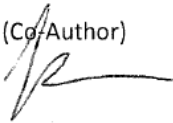
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Statement of Contribution

I, Jennie Musto, attest that Research Higher Degree candidate Beverley Paterson contributed substantially – in terms of study concept and design, data collection and analysis, preparation and revision of the manuscript – to the publication:

Kool JL, Paterson B, Pavlin BI, Durrheim D, Musto J, Kolbe A. **Pacific-wide simplified syndromic surveillance for early warning of outbreaks.** Glob Public Health. 2012;7(7):670-81.

Jennie Musto (Co-Author)



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I, Boris Pavlin, attest that Research Higher Degree candidate Beverley Paterson contributed substantially – in terms of study concept and design, data collection and analysis, preparation and revision of the manuscript – to the publications:

Kool JL, Paterson B, Pavlin BI, Durrheim D, Musto J, Kolbe A. **Pacific-wide simplified syndromic surveillance for early warning of outbreaks.** Glob Public Health. 2012;7(7):670-81.

and

Paterson BJ, Kool JL, Durrheim DN, Pavlin B: **Sustaining surveillance: evaluating syndromic surveillance in the Pacific.** Glob Public Health. 2012;7(7):682-694.

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Statement of Contribution

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Presanis AM, Pebody RG, Paterson BJ, Tom BD, Birrell PJ, Charlett A, Lipsitch M, De Angelis D:
Changes in severity of 2009 pandemic A/H1N1 influenza in England: a Bayesian evidence synthesis.
BMJ 2011, **343**:d5408.

Richard Pebody (Co-Author)

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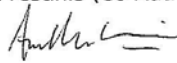
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Statement of Contribution

I, Anne Presanis, attest that Research Higher Degree candidate Beverley Paterson contributed substantially – in terms of data collection, contribution to model development and revision of the manuscript – to the publication:

Presanis AM, Pebody RG, Paterson BJ, Tom BD, Birrell PJ, Charlett A, Lipsitch M, De Angelis D: **Changes in severity of 2009 pandemic A/H1N1 influenza in England: a Bayesian evidence synthesis**. *BMJ* 2011, **343**:d5408.

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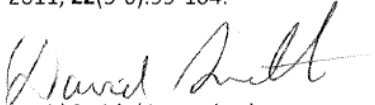
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Statement of Contribution

I, David Smith, attest that Research Higher Degree candidate Beverley Paterson contributed substantially – in terms of study concept, preparation, writing and revision of the manuscript – to the publication:

Paterson BJ, Mackenzie JS, Durrheim DN, Smith D: **A review of the epidemiology and surveillance of viral zoonotic encephalitis and the impact on human health in Australia.** *NSW Public Health Bull* 2011, **22**(5-6):99-104.


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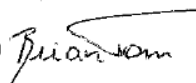
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Statement of Contribution

I, Brian Tom, attest that Research Higher Degree candidate Beverley Paterson contributed substantially – in terms of data collection, contribution to model development and revision of the manuscript – to the publication:

Presanis AM, Pebody RG, Paterson BJ, Tom BD, Birrell PJ, Charlett A, Lipsitch M, De Angelis D:
Changes in severity of 2009 pandemic A/H1N1 influenza in England: a Bayesian evidence synthesis.
BMJ 2011, **343**:d5408.

Brian Tom (Co-Author)



Date: 06/02/13

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Statement of Contribution

I, Frank Tuyl, attest that Research Higher Degree candidate Beverley Paterson contributed substantially – in terms of study concept and design, data collection and analysis, preparation and revision of the manuscript – to the publication:

Paterson B, Durrheim DN, Tuyl F: **Influenza: H1N1 goes to school**. *Science* 2009, **325**(5944):1071-1072; author reply 1072-1073.

Frank Tuyl (Co-Author)



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4/2/13

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GLOSSARY OF TERMS AND ABBREVIATIONS

ABLV	Australian Bat Lyssavirus
AHPC	Australian Health Protection Committee
AFP	Acute Flaccid Paralysis
APSU	Australian Paediatric Surveillance Unit
AQIS	Australian Quarantine and Inspection Service
Bayesian	A method of statistical inference that begins with the state of knowledge, i.e., the facts, prior to an exposure or an intervention, and augments this with study data to yield the state of knowledge posterior to the study [1]
Case Fatality Rate	The number of deaths due to a specific disease as compared with the total number of cases of the disease [2]
CDNA	Communicable Disease Network of Australia
DAFF	Department of Agriculture, Fisheries and Forestry
DoHA	Department of Health and Ageing
ERLNA	Enterovirus Reference Laboratory Network of Australia
GBS	Guillain–Barré Syndrome
HeV	Hendra virus
IHR	International Health Regulations
ILI	Influenza-like-illness
IPV	Inactivated Poliomyelitis Vaccine
JEV	Japanese encephalitis virus
LDC	Least developed countries
MVEV	Murray Valley encephalitis virus
NCC	National Certification Committee
NERL	National Enterovirus Reference Laboratory
NPRL	National Polio Reference Laboratory
NOCS	Queensland Notifiable Conditions System
Outbreak	An epidemic limited to localized increase in the incidence of disease [1]
PAEDS	Paediatric Active Enhanced Disease Surveillance

Pandemic	An epidemic occurring worldwide, or over a very wide area, crossing international boundaries, and usually affecting a large number of people [1]
PEP	Polio Expert Panel
PICTs	Pacific Island Countries and Territories
Public health	Health of the whole population or community
OPV	Oral Poliomyelitis Vaccine
R	Effective reproduction number – average number of secondary infectious persons resulting from one infectious person in a given population in which some individuals may already be immune because of infection or vaccination [3]
R_0	Basic reproduction number – the average number of secondary infectious persons resulting from one infectious person following their introduction into a totally susceptible population [3]
SARS	Severe Acute Respiratory Syndrome
Sensitivity	The proportion of cases of a disease detected by the surveillance system or the ability of the system to detect outbreaks, including the ability to monitor changes in the number of cases over time [2]
Sensitivity analysis	A method to determine the robustness of an assessment by examining the extent to which results are affected by changes in methods, values of variable, or assumptions [1]
Serial interval	Time interval between successive infections in a chain of transmission [3]
SPC	Secretariat of the Pacific Community
SSBA	Security Sensitive Biological Agents
Surveillance	The ongoing, systematic collection, collation, analysis of data and the timely dissemination of those who need to know so that action can be taken [1]
Syndrome	A symptom complex in which the symptoms and/or signs coexist more frequently than would be expected by chance [1]

Syndromic surveillance	Surveillance system using a case definition based on symptoms or indicators, not requiring laboratory confirmation, which provides data for public health purposes
TGA	Therapeutic Goods Administration
Timeliness	Reflects the speed between the steps in a public health surveillance system [4]
Triangulation	The use of a variety of data in a study to validate the findings [5]
VAPP	Vaccine-Associated Paralytic Poliomyelitis
VIDRL	Victorian Infectious Diseases Reference Laboratory
WNV	West Nile virus
WHA	World Health Assembly
WHO	World Health Organization

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