

The 'One Health' paradigm: Time for infectious diseases clinicians to take note?

David N Fisman MD MPH FRCPC¹, Kevin B Laupland MD MS FRCPC²

What do severe acute respiratory syndrome (SARS), monkeypox, highly pathogenic influenza A, new variant Creutzfeld-Jacob disease, cryptosporidiosis and verotoxigenic *Escherichia coli* have in common? All represent infectious diseases that have emerged, been recognized or changed their distribution markedly over the past three decades, and all may be considered to be 'zoonotic' threats; ie, they are diseases (or commensal microbes) found in animals that can be transmitted to humans, causing disease in the latter. The preponderance of zoonoses among emerging infectious diseases is striking: a pre-SARS Institute of Medicine (USA) report (1) suggested that approximately three-quarters of emerging infections originated in animals. Zoonotic threats become an even greater menace when combined with the rapidity of air travel, and the high volumes of animal trafficking and smuggling that currently occur. SARS was an infectious threat that moved from a natural reservoir (likely bats) to civet cats in animal markets in Guangdong province, China, and were then carried by infected humans to the hospitals of Toronto, Ontario, in a few short months (2). Similarly, an Old World virus causing West Nile virus fever and encephalitis emerged as a novel infectious entity in the western hemisphere in 1999, possibly following illicit animal importation into New York (USA) (3,4). The list goes on.

Although these recent events show animal health and human health to be integrally connected, few clear lines of communication exist between veterinary and medical professionals with respect to preventive medicine and public health, clinical practice or research. The potential advantages of greater integration 'across species' have been identified and documented by individuals involved in the 'One Health Initiative' (www.onehealthinitiative.com) (5). The One Health Initiative was founded by Dr Laura Kahn (a physician at Princeton University [New Jersey, USA]), Dr Bruce Kaplan (a retired veterinarian formerly with the United States Centers for Disease Control and Prevention, and the United States Department of Agriculture's Food Safety Inspection Service) and Dr Tom Monath (a physician and former Division Director at the Centers for Disease Control and Prevention, and the United States Army Medical Research Institute for Infectious Diseases). More recently, the group has been joined by Jack Woodall, a cofounder and Associate Editor of ProMED-mail.

The One Health concept has won endorsement from many professional societies, including the American Medical Association (6) and the American Veterinary Medical Association (7), and has had its principles endorsed by the

Royal Society (London, United Kingdom) (8). The mission of the One Health Initiative, as articulated on the group's website, includes fostering joint educational efforts among medical, veterinary and public health schools; joint communication (in publications and conferences, and via networking); joint efforts aimed at clinical care and prevention, and efforts aimed at cross-species surveillance; fostering of comparative medical research; joint development of diagnostic methodologies; and joint advocacy aimed at educating leaders and the public (9). One Health as a concept has been embraced by Canadian veterinary schools; eg, the University of Calgary's new Faculty of Veterinary Medicine (Calgary, Alberta) has a stated commitment to One Health (10), and the One Health model is very much in step with the recent establishment of a Centre for Public Health and Zoonosis at the University of Guelph/Ontario Veterinary College (Guelph, Ontario) (11).

Given the rapid embrace of the One Health concept by both medical and veterinary medical public health officials, one must ask, "What do we expect to gain through realization of a One Health paradigm, at the level of patient care, and at the level of health and public health policy? What are the barriers to its realization? Are there instances of moral hazard or perverse incentives that may prevent achievement of One Health?"

It is clear that medical and veterinary practitioners find health issues, including infectious disease threats that occur at the interspecies interface, to be a source of confusion. This is perhaps best documented in veterinary medicine. For example, Kahn (12) surveyed 1070 veterinarians in the United States, specifically, in New York, New Jersey, Pennsylvania and New Hampshire, about who they would contact regarding unusual infectious diseases in both companion animals (pets) and livestock animals. Responses varied widely: for companion animals, 30% of veterinarians indicated that they would notify a state agricultural agency, while 42% indicated that they would contact a local or state public health agency. For livestock animals, most veterinarians (70%) indicated that they would contact an agricultural agency or the state veterinarian, while 19% indicated that they would notify a public health agency (12).

Documents outlining the One Health paradigm emphasize the degree to which One Health has deep roots in medical research, with pioneering medical researchers including Giovanni Maria Lancisi (13) (a medical lexicographer and the first physician to suggest the use of window screens for malaria prevention in the 18th century), Sir William Osler (14,15) (who taught at the Montreal Veterinary College as well as at the

¹Dalla Lana School of Public Health and Department of Health Policy, Management and Evaluation, University of Toronto, and Department of Medicine, North York General Hospital, Toronto, Ontario; ²Departments of Medicine, Critical Care Medicine, Pathology and Laboratory Medicine, Centre for Antimicrobial Resistance, University of Calgary, Calgary Laboratory Services, Calgary Health Region, Calgary, Alberta
Correspondence: Dr David N Fisman, Dalla Lana School of Public Health, 155 College Street, Room 678, Toronto, Ontario M5T 3M7.
Telephone 416-978-6866, fax 416-978-7735, e-mail david.fisman@utoronto.ca

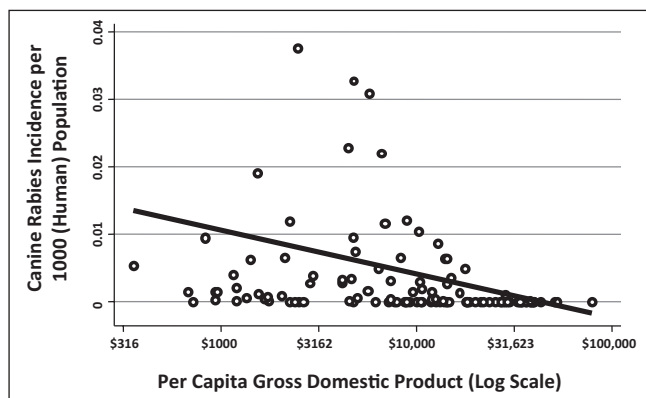


Figure 1) Canine rabies cases and per capita gross domestic product (GDP). A linear relationship is seen between the number of rabies cases in dogs/1000 (human) population in 2007 or 2009, and $\log_{10}$ of per capita GDP for 121 countries with data available. Least squares regression reveals a statistically significant relationship (reduction of 0.007 cases/1000 population for every $\log_{10}$ increase in per capita GDP, 95% CI -0.002 to -0.01 ; $P=0.004$). Rabies case data were obtained from reference 42, while country population and GDP data were obtained from reference 43

McGill University Medical School in Montreal, Quebec, and who was dispatched to investigate a swine typhoid outbreak during his tenure in Montreal) and Rudolf Virchow (the pioneering pathologist and social reformer who was the first to identify *Trichinella spiralis* as a parasitic infection of swine, as opposed to a normal microscopic feature of pork) (16) – these researchers freely crossed disciplinary lines to apply their skills and intellects to veterinary problems (17). How was this transdisciplinary spirit lost? In part, this divergence must reflect the institutional growth and increasing complexity of human and veterinary medicine, as each knowledge base has grown, it has become progressively difficult for practitioners to contemplate the vast amount of information that exists on the other side of the ‘species divide’. Indeed, even within the disciplines, there is a narrowness of vision that has been bred by increasing specialization – a phenomenon referred to by medical humanist Dr Victor Bressler as “a medical tower of Babel” (18).

However, it seems that simple disciplinary growth is not enough to explain the degree to which medical and veterinary enterprises have become dissociated. A second factor, at least on the medical side, may be the fact that clinical medicine is focused on individuals and rooted in Hippocratic tenets, rather than on populations. Veterinarians are familiar with the idea of intervening at the level of the ‘herd’. Historian David Wootton notes that the reluctance to group or aggregate cases (pioneered by Pierre Louis in his investigations on bleeding as a treatment for pneumonia) was based largely on Hippocratic principles that regarded each case of disease as a ‘one-off’. This line of thinking delayed the emergence of meaningful clinical epidemiological research until well into the 19th century (19). Focusing on individuals, rather than the populations (human or animal) with which they interact, or the ecosystems from which they are drawn, may make it difficult to understand and to appreciate the interaction between populations. We can still see echoes of this on current day Internal Medicine board examination questions: human-animal interactions are framed

in terms of bird ownership when the diagnosis is psittacosis, interaction with a parturient sheep for Q fever, or an animal bite in the context of antimicrobial choice. However, the myriad human-animal and human-animal-environment interactions that may contribute to health and disease including shared environmental exposures, pet ownership and animal companionship, food production and consumption, and trade are largely regarded as background noise.

Physicians, similar to other nonveterinarians and nonfarmers, lack an experiential framework that makes the ecology and health of animals, especially food animals, meaningful to them. William Osler lived in a world of horse-drawn transportation, and, similar to most Canadians, had come of age in rural areas of Ontario (Bond Head and Dundas). Most current Canadian medical professionals (similar to the public at large) live and work in urban or suburban environments, and experience representations of agriculture mostly through advertising on milk cartons, meat packaging and consumer websites that are emblazoned with images of small numbers of animals grazing on single-family farms that have not been representative of mainstream agriculture for more than 50 years. Author Jonathan Safran Foer has recently written a best-selling polemic related to animal agriculture in the United States, entitled *Eating Animals*, much of which is devoted to describing the complex games played with language to avoid talking about the gritty realities of industrial-scale food production (20). Current and past yield-increasing practices may be associated with animal crowding, widespread antimicrobial exposure, ecosystem disruption (21) and (in the case of bovine spongiform encephalopathy) de facto animal cannibalism (22); each of these practices has important epidemiological and environmental implications of human health importance (1). The former two factors (crowding and antibiotic pressure) will be familiar to readers who evaluate risks for emergence of antimicrobial-resistant organisms in nosocomial settings (23,24).

Perhaps the greatest benefit to be reaped via a One Health framework can be found in low- and middle-income countries that have not yet developed extensive veterinary health and food safety frameworks, which have already been developed in wealthier countries at the beginning of the 20th century. In less developed countries, food production uses a larger fraction of the population and, consequently, direct contact with both farmed animals and feral animals living in the vicinity of farms may be increased. Traditional hunting and consumption of ‘bush meat’ may be common means of supplementing farmed foods (bush meat consumption has been linked to human infections with HIV, Ebola and other zoonotic diseases [25]). The absence of veterinary human resource capacity means that disease threats, such as human rabies (now vanishingly rare in high-income countries, and largely preventable via vaccination of dogs and cats), are common causes of lost life-years in humans (26). Veterinarians figure prominently in optimal approaches to the protection of human health, whether via vaccination or through participation in regulatory activities such as meat inspection. The importance of veterinary capacity to human health in lower-income countries can be demonstrated quantitatively by plotting reported canine rabies cases against countries’ per capita gross domestic product, as in Figure 1.

Thus, it is perhaps not surprising that an ‘early adopter’ of the One Health model has been the WHO’s program on

neglected tropical diseases, which has collaborated with veterinary partners such as the United Nation Food and Agricultural Organization and the Organization Internationale des Epizooties to publish the report of a meeting on integrating approaches to controlling neglected zoonoses including bovine tuberculosis, brucellosis, echinococcosis and rabies (26) – all of which remain hyperendemic in Africa. As the report notes, the mixed human-veterinary nature of neglected zoonotic diseases (NZD) has “led to...NZD falling into the gap between veterinary responsibilities and medical needs...[a] comprehensive, interdisciplinary approach is therefore needed to address the major obstacles to control NZD” (26). Specific recommendations that emerged from this meeting included global leadership on NZD that explicitly incorporates a One Health approach, and recommendations to develop joint medical-veterinary approaches to surveillance, control and advocacy. Another established model of human-veterinary cooperation that involves integration of human and animal surveillance activities is the OFFLU network, which integrates laboratory input from the United Nations Food and Agriculture Organization, Organisation Mondiale de la Santé Animale and the WHO to counter the threat posed by avian influenza strains (such as influenza A) to both avian and human populations (27).

The high degree of mobility of animals, via trade in food animals, pets and animal products, means that zoonotic threats are never confined to the countries in which they originate. In 2003, the midwestern United States experienced a monkeypox outbreak, which emphasized the degree to which exotic human diseases can be rapidly introduced into new ranges via trade of infected animals (28); the genesis of West Nile virus importation into the western hemisphere may have similarly been a result of illicit animal trade (29). Mass gatherings (for sporting or religious events) have been identified as important epidemiological events that may foster the movement of infectious diseases (30,31); it is often forgotten that for such events, mass movement of food animals to supply event participants may be needed, which may introduce zoonotic diseases into new ranges or reintroduce disease into areas from which it has been eliminated. For example, the Hajj pilgrimage to Saudi Arabia necessitates the importation of millions of animals for food and ritual purposes; a substantial fraction of these come from countries where brucellosis is poorly controlled, making veterinary disease control an important component of the public health protection provided to pilgrims (32).

The highly mobile nature of animals and animal products means that zoonotic disease threats in low- and middle-income countries are of direct relevance to public health authorities in high-income countries such as Canada. It is perhaps less clear why clinical medical practitioners should embrace a One Health framework. One might, however, argue that understanding of the way systems work, and awareness of threats, is important to physicians making difficult diagnoses in individuals with zoonotic illness. The tendency to ignore diagnostic possibilities that are not fresh in the mind of the individual clinician is referred to as the ‘availability heuristic’ (33).

Perhaps more importantly, physicians can be important advocates for health and safety practices outside the clinic; a defining paradox of disease-control activities is the fact that once success is achieved (eg, in the control of such zoonotic threats as bovine tuberculosis or brucellosis), there is a tendency on the part of the

public and some medical professionals to question the necessity of interventions that produced such health yields (34). This paradox fits well with the economic concept of public goods that tend to require vigorous enforcement via external regulation because parties directly involved in transactions may have little motivation to sustain an apparatus aimed at preventing a threat that they see as nonexistent (35). Recent controversies in Ontario around enforcement of milk pasteurization fit well with such a model (36), and having primary care and specialist physicians onside with respect to the potential threat posed by unsafe foods to patients can be an important means of influencing public opinion.

In the United States, recent congressional hearings have focused on the role of agricultural antibiotic use in the genesis of antimicrobial resistance in humans (37). Human health experts, including representatives from the Infectious Disease Society of America (IDSA) have been eloquent in their testimony supporting a proposed bill to limit the use of antimicrobials in agriculture to preserve agents for the treatment of serious infections in humans (38). Dr James Johnson, representing the IDSA, told the House of Representatives Committee on Energy and Commerce’s Subcommittee on Health that the IDSA supports “elimination of non-judicious uses [of antimicrobials including]...for purposes of growth promotion, feed efficiency, and routine disease prevention” (38).

While integration and cooperation sound good, there may be potential downsides to closer cooperation. Emphases of these two communities may be different; a recent discussion on the infectious disease list-server ProMED-mail (www.promedmail.org) considered the potential importance of the emergence of a novel strain of methicillin-resistant *Staphylococcus aureus* (ST398) in pig and horse populations (39), and evidence that this strain is now colonizing human agricultural workers. A veterinary epidemiologist indicated that the cross-sectional prevalence of active infection appeared to be low in the workers themselves; however, an infectious diseases physician expressed concern that this strain could ultimately colonize large numbers of individuals outside the animal husbandry sector (40). Assessment of risk is not the only point of potential contention: a new focus by human health experts on the potential microbial risks associated with food production and animal trade and ecology may have economic impacts on food producers (41), and may limit the degree to which interdisciplinary information sharing and cooperation is possible.

While we are optimistic that such barriers can be overcome, there are substantial institutional and cultural barriers to greater integration and communication between veterinary and medical professionals in Canada. Animal health has, by and large, been overseen by agricultural authorities whose goals may (under certain circumstances) diverge from those of human health authorities. While data sharing, integrated surveillance systems, training and research programs, and advocacy are something to strive for, we believe that spreading the word about One Health as a concept germane to the practice of communicable disease control is a good place to start.

ACKNOWLEDGEMENT: The authors thank Drs Bruce Kaplan, Laura Kahn and Tom Monath for their useful comments on this article.

REFERENCES

1. Lederberg J, Shope RE, Oaks SC, eds. Factors in emergence. Emerging Infections: Microbial Threats to Health in the United States. Washington: National Academies Press, 1992:34-112.
2. Peiris JS, Guan Y. Confronting SARS: A view from Hong Kong. Philos Trans R Soc Lond B Biol Sci 2004;359:1075-9.
3. Mostashari F, Bunning ML, Kitsutani PT, et al. Epidemic West Nile encephalitis, New York, 1999: Results of a household-based seroepidemiological survey. Lancet 2001;358:261-4.
4. Jia XY, Briese T, Jordan I, et al. Genetic analysis of West Nile New York 1999 encephalitis virus. Lancet 1999;354:1971-2.
5. Kahn LH, Kaplan B, Monath TP. 'One health' in action series: Nos 1-8. Vet Ital 2009;45:195-208.
6. Kahn LH. 'One Medicine – One Health' interview with Ronald M Davis, MD, President of the American Medical Association, 14 May 2008. Vet Ital 2009;45:19-21.
7. King LJ, Anderson LR, Blackmore CG, et al. Executive summary of the AVMA One Health Initiative Task Force report. J Am Vet Med Assoc 2008;233:259-61.
8. Dorans K. Royal Society urges integration of human and veterinary medicine. Nat Med 2009;15:227.
9. One Health Initiative. Mission statement. <www.onehealthinitiative.com/mission.php> (Accessed on July 12, 2010).
10. University of Calgary. Faculty of Veterinary Medicine. <www.vet.ucalgary.ca/about_UCVM> (Accessed on July 12, 2010).
11. University of Guelph. Centre for Public Health and Zoonoses. <www.ovc.uoguelph.ca/cphaz/> (Accessed on July 12, 2010).
12. Kahn LH. Confronting zoonoses, linking human and veterinary medicine. Emerg Infect Dis 2006;12:556-61.
13. Mantovani A, Zanetti R, Giovanni Maria Lancisi: De bovilla peste and stamping out. Hist Med Vet 1993;18:97-110.
14. Teigen PM. William Osler and comparative medicine. Can Vet J 1984;25:400-5.
15. Murphy DA. Osler, now a veterinarian. Can Med Assoc J 1960;83:32-5.
16. Saunders LZ. Virchow's contributions to veterinary medicine: Celebrated then, forgotten now. Vet Pathol 2000;37:199-207.
17. Kahn LH, Kaplan B, Monath TP, Steele JH. Teaching "one medicine, one health". Am J Med 2008;121:169-70.
18. Bressler V. Medical humanism and professionalism teaching in a community hospital since World War II. In: The Pennsylvania Medical Humanities Consortium: Through the Lens of Time: Perspectives on Medicine and Health Care. Philadelphia, 2010.
19. Wootton D. The Hippocratic tradition. In: Bad Medicine: Doctors Doing Harm Since Hippocrates. Oxford: Oxford University Press, 2006:27-70.
20. Safran Foer J. Eating Animals, 1st edn. New York: Little, Brown and Co, 2009.
21. Heymann DL. Social, behavioural and environmental factors and their impact on infectious disease outbreaks. J Public Health Policy 2005;26:133-9.
22. Prusiner SB. Prion diseases and the BSE crisis. Science 1997;278:245-51.
23. Lawton RM, Fridkin SK, Gaynes RP, McGowan JE Jr. Practices to improve antimicrobial use at 47 US hospitals: The status of the 1997 SHEA/IDSA position paper recommendations. Society for Healthcare Epidemiology of America/Infectious Diseases Society of America. Infect Control Hosp Epidemiol 2000;21:256-9.
24. Harbarth S, Sudre P, Dharan S, Cadenas M, Pittet D. Outbreak of *Enterobacter cloacae* related to understaffing, overcrowding, and poor hygiene practices. Infect Control Hosp Epidemiol 1999;20:598-603.
25. Peterson D, Ammann K. Eating Apes. Berkeley: University of California Press, 2004.
26. World Health Organization. Integrated control of neglected zoonotic diseases in Africa: Applying the "One Health" concept. Report of a Joint WHO/EU/ILRI/DBL/FAO/OIE/AU Meeting. Nairobi: International Livestock Research Institute, 2007.
27. OFFLU-OIE/FAO Network of Expertise on Animal Influenza. <http://offlu.net/> (Accessed on May 21, 2010).
28. Reed KD, Melski JW, Graham MB, et al. The detection of monkeypox in humans in the Western Hemisphere. N Engl J Med 2004;350:342-50.
29. Giladi M, Metzkor-Cotter E, Martin DA, et al. West Nile encephalitis in Israel, 1999: The New York connection. Emerg Infect Dis 2001;7:659-61.
30. Khan K, Freifeld CC, Wang J, et al. Preparing for infectious disease threats at mass gatherings: The case of the Vancouver 2010 Olympic Winter Games. CMAJ 2010;182:579-83.
31. Khan K, Memish ZA, Chhabra A, et al. Global public health implications of a mass gathering in Mecca, Saudi Arabia during the midst of an influenza pandemic. J Travel Med 2010;17:75-81.
32. Memish Z. Brucellosis control in Saudi Arabia: Prospects and challenges. J Chemother 2001;(13 Suppl 1):11-7.
33. Kassirer JP, Koppelman RI. Diagnostic hypothesis generation. In: Learning Clinical Reasoning. Baltimore: Williams and Wilkins, 1991.
34. Bauch CT, Earn DJ. Vaccination and the theory of games. Proc Natl Acad Sci U S A 2004;101:13391-4.
35. Fisman DN, Laupland KB. The sounds of silence: Public goods, externalities, and the value of infectious disease control programs. Can J Infect Dis Med Microbiol 2009;20:39-41.
36. Weir E, Mitchell J, Rebellato S, Fortuna D. Raw milk and the protection of public health. CMAJ 2007;177:721-3.
37. Selyukh A. Officials seek limits on livestock antibiotics. <www.reuters.com/article/idUSTRE66E0C220100715> (Accessed on July 22, 2010).
38. United States Committee on Energy and Commerce. The Infectious Diseases Society of America's (IDSA) statement on antibiotic resistance: Promoting judicious use of medically important antibiotics in animal agriculture, July 14, 2010. <http://energycommerce.house.gov/documents/20100714/Johnson.Testimony.07.14.2010.pdf> (Accessed on July 20, 2010).
39. Golding GR, Bryden L, Levett PN, et al. Livestock-associated methicillin-resistant *Staphylococcus aureus* sequence type 398 in humans, Canada. Emerg Infect Dis 2010;16:587-94.
40. ProMED-mail. Antibiotic resistance & agricultural uses – USA (03). <www.promedmail.org> (Accessed on July 12, 2010).
41. McKay PA, Cui C. Flu outbreak depresses markets. <http://online.wsj.com/article/SB124082918450558901.html> (Accessed on July 9, 2010).
42. RabNet. <http://apps.who.int/globalatlas/default.asp> (Accessed on July 10, 2010).
43. The World Factbook. <https://www.cia.gov/library/publications/the-world-factbook/index.html> (Accessed on July 10, 2010).