Confronting zoonoses through closer collaboration between medicine and veterinary medicine (as 'one medicine')

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Summary

In the 19th century, the concept of 'one medicine' was embraced by leaders in the medical and veterinary medical communities. In the 20th century, collaborative efforts between medicine and veterinary medicine diminished considerably. While there have been some notable exceptions, such as Calvin W. Schwabe's proposal for unifying human and veterinary medicine and joint efforts by the Food and Agriculture Organization and World Health Organization to control zoonotic diseases, 'one medicine' has languished in the modern milieu of clinical care, public health, and biomedical research. Risks of zoonotic disease transmission are rarely discussed in clinical care which is of particular concern if humans and/or animals are immunosuppressed. Physicians and veterinarians should advise their patients and pet-owning clients that some animals should not be pets. The risk of zoonotic disease acquisition can be considerable in the occupational setting. Collaborative efforts in biomedical research could do much to improve human and animal health. As the threat of zoonotic diseases continues to increase in the 21st century, medicine and veterinary medicine must revive 'one medicine' in order to adequately address these challenges. 'One medicine' revival strategies must involve medical and veterinary medical education, clinical care, public health and biomedical research.

Keywords

Biomedical research, Collaboration, Education, One medicine, Physicians, Veterinarians, Zoonoses.

Affrontare le zoonosi attraverso una più stretta collaborazione tra la medicina umana e veterinaria (intese come "medicina unica")

Riassunto

Nel diciannovesimo secolo, il concetto di "medicina unica è stato abbracciato dai leader delle comunità mediche e veterinarie, mentre nel ventesimo secolo gli sforzi di collaborazione tra la medicina e la medicina veterinaria sono considerevolmente diminuiti. Pur essendoci alcune eccezioni degne di nota, come la proposta di Calvin W. Schwabe di unificare la medicina umana e veterinaria, e gli sforzi congiunti di FAO (Food and Agriculture Organization) e OMS (Organizzazione Mondiale

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della Sanità) per il controllo delle zoonosi, la "medicina unica" ha languito nello scenario moderno di clinica, sanità pubblica e ricerca biomedica. I rischi di trasmissione di zoonosi vengono discussi di rado in ambito clinico pur essendo di particolare interesse in caso di esseri umani e /o animali immunosoppressi. Sarebbe opportuno che medici e veterinari avvisassero i pazienti e i clienti possessori di animali da compagnia che alcuni di questi animali non dovrebbero essere considerati tali, ed il rischio di contrarre una zoonosi può essere alto nell'ambiente professionale. Gli sforzi di collaborazione nella ricerca biomedica potrebbero far molto per migliorare la salute umana e animale. Dato che la minaccia rappresentata dalle zoonosi continua ad aumentare nel ventunesimo secolo, la medicina e la veterinaria devono ristabilire "la medicina unica" al fine affrontare in modo adeguato queste sfide, e le strategie di ripristino devono comprendere la formazione medica e quella medico-veterinaria, la clinica, la sanità pubblica e la ricerca biomedica.

Parole chiave
Collaborazione, Formazione, Medicina unica, Medici, Ricerca biomedica, Veterinari, Zoonosi.

Introduction

The goal of this paper is to provide a historical overview and current assessment of the level of collaborations, the embracing of 'one medicine,' by the human and veterinary medical communities. Recommendations will be made on how to increase joint efforts between these two professions. Historically, some of the greatest names in medicine and veterinary medicine have embraced the 'one medicine' concept. Unfortunately, 'one medicine' has languished in recent decades, but given the challenges of emerging zoonotic diseases in the 21st century, it must be reinvigorated and incorporated on a global scale.

Historical perspective

The interrelationship between human and veterinary medicine was recognised in the 19th century by the German physician and pathologist, Rudolf Virchow (1821-1902). Referred to by many as the founder of (or 'father of') comparative medicine, cellular biology and veterinary pathology, Virchow coined the term 'zoonosis'. He said, 'between animal and human medicine there are no dividing lines – nor should there be. The object is different but the experience obtained constitutes the basis of all medicine' (16, 40, 58, 59).

Virchow's strong support of veterinary medicine led to the development of veterinary pathology and the establishment of public health meat inspection programmes throughout Europe and subsequently in the United States. In fact, the basis for modern day public health meat and poultry inspection programmes can be largely attributed to him (58, 59). Hence, veterinarians have subsequently inherited the primary role as inspectors-in-charge in federally inspected meat and poultry plants in the United States because they have the professional animal pathology expertise.

The Canadian physician Sir William Osler (1849-1919), known as the father of modern medicine, studied with Virchow in Berlin and was an early admirer of his work. He subsequently taught parasitology and physiology at the Montreal Veterinary College in addition to his duties at the McGill University medical school. Using Virchow's methods for autopsy techniques and scientific inquiry, he later began teaching pathology to veterinary students as he had been doing with his medical students. Eventually, the Montreal Veterinary College became affiliated with McGill as the Faculty of Comparative Medicine and Veterinary Science.

While at Montreal Veterinary College, Osler conducted research on hog cholera (classical swine fever) (1878), verminous bronchitis of dogs (1877), Pictou cattle disease (1883) and others. He worked closely with veterinarians, including one of his veterinary students, Albert W. Clement, a future President of the United States Veterinary Medical Association (now the American Veterinary Medical Association, or AVMA) (57, 62). Clement graduated in 1882. In 1883, Osler and Clement published case reports on bronchiectasis in a calf, chronic bronchitis in a dog, pyometra in a bitch and experimental production of tapeworm cysts in a calf; the latter experiment was performed to serve as a model demonstrating the life-cycle for medical and veterinary medical students at the time. Osler taught veterinary students from 1876 to 1884 and, although a relatively short period of time, contributed greatly to the field of veterinary pathology and veterinary medicine (16, 57).

James Law (1838-1921), a veterinarian, was educated at the Edinburgh Veterinary College and the medical school at Edinburgh University. He was also trained in France at the veterinary schools in Alfort and Lyons. Law was recruited in 1868 from the University of Edinburgh with the recommendation of John Gamgee (1831-1894), a famous British veterinarian. Thus, he became the first professor of veterinary medicine in the United States, at Cornell University, and later the first dean of the New York State Veterinary College. Law had co-authored with Gamgee a well-illustrated volume on anatomy of domestic animals in 1862 (16). Law became a leader in public health and was a scientist who believed in 'one medicine' where physicians and veterinarians should have close relations. His work on tuberculosis, foot and mouth disease and other epizootics had a profound effect on animal and human health in America. He chose his first student to be Daniel E. Salmon who became the first graduate Doctor of Veterinary Medicine (DVM) qualified in the United States. Salmon became the founder of the United States Department of Agriculture's (USDA) Bureau of Animal Industry (BAI) and was joined there by Theobald Smith (1859-1934), a physician, and Frederick L. Kilborne (1858-1936), a veterinarian (4, 16).

An epoch-making discovery was made by Salmon and Smith while studying hog cholera. Together they demonstrated that dead organisms killed by heat could immunise animals against living disease organisms. This was the foundation for development of a vaccine against typhus and Jonas Salk's (1914-1995) production of polio vaccine; these are still saving children from death or crippling disease today (6).

Salmon is associated with a number of other important developments in infectious disease pathology, most notably with his demonstration of the transmissibility to humans of tuberculosis from cattle, thereby confirming the role of animal vectors in the spread of the disease. Salmon was honoured by his European colleagues when they named the common intestinal infectious bacteria S*almonella* after him. He was also president of the American Public Health Association (APHA) and the AVMA (6).

In 1879 the United States Congress created a national board of health. The board consisted solely of government physicians from the army, navy, public health hospital service and justice department. They invited Law to be a consultant. Previously, Law had stressed the value of veterinary medical knowledge and service to public health in an 1878 report of animal diseases and highlighted the importance of their transmissibility to man. In 1879, Law reported to the United States board of health a list of diseases that were important to veterinary medicine as well as public health. He further stated in the report that veterinarians should receive public health training and physicians should receive knowledge of the zoonoses. Sixty years later, the first veterinarians with public health training graduated from Harvard (64).

The APHA scheduled reports on animal diseases at its first meeting in 1873. Among the first titles at that meeting was a report on the epizootic among horses which was identified as influenza. Later, there were other papers on equine influenza, trichinosis and Texas fever by both medical doctors (MDs) and DVMs. It should be noted that state boards of health were involved in animal disease surveillance and prepared reports on animal diseases up to the 20th century (64).

The early 20th century saw a rekindled interest in comparative medicine by pathologists, led by Karl F. Meyer (1884-1974), a Swiss veterinarian. Meyer became an outstanding leader and scientist. He delved into virology while a professor of pathology at the University of Pennsylvania School of Veterinary Medicine. In 1913, he is believed to have been the first to recover a virus causing equine encephalitis. Meyer subsequently published information on glanders, anthrax, anaplasmosis, sporotrichosis, paratuberculosis, septicaemia and many other animal diseases. He became legendary at the George Williams Hooper Foundation for Medical Research at the University of California Medical Center. Meyer lectured medical students on zoonoses, plant life and the atmosphere. Among many other viral research activities, Meyer actively investigated human influenza from 1918 to 1920 (16, 65).

Meyer died in 1974. In his obituary in the *New York Times*, medical writer and physician, Lawrence K. Altman wrote, 'Karl Friedrich Meyer was regarded as the most versatile microbe hunter since Louis Pasteur and a giant in public health… His scientific work had such broad implications that it touched on virtually all fields of medicine' (2, 65).

Another milestone in United States veterinary medical history was the marked reduction of the leading cause of death in the early 20th century in humans: tuberculosis (TB). Veterinary disease control measures in cattle, which accounted for 40% to 50% of the human disease burden at the time, was largely responsible for reducing to near zero the transmission of *Mycobacterium bovis* to humans (47).

The human-to-human transmission of *Mycobacterium tuberculosis* continued relatively unabated until the introduction of the BCG (bacillus Calmette-Guérin) vaccine and streptomycin in the 1940s; these two discoveries are credited with another dramatic reduction in the devastating human toll of the disease (52). While BCG vaccine is not generally recommended today in the United States, it is used in many countries with a high tuberculosis prevalence (8).

The BCG vaccine was used increasingly in Europe during the early 1920s (77). It was developed by Albert Calmette (1863-1933), a French physician, bacteriologist and immunologist and Jean-Marie Camille Guérin (1872-1961), a French veterinarian, bacteriologist and immunologist (16, 75). Regrettably, Guérin's background in veterinary medicine and monumental collaborative contribution with a physician (which argues well for the 'one medicine' concept) have not only largely been forgotten but are also rarely noted within today's public health and physician communities.

BCG was developed from *M. bovis* isolated from a cow in the early 1900s. The vaccine failed to be of value in the control of TB in cattle in studies by Calmette and Guérin and later by the USDA's BAI and some trials conducted in England. In the 1920s, human trials led to controversy in Europe and the United States in regard to human protection. Neither the United States Public Health Service (USPHS) nor the Animal Health Services ever endorsed the use of BCG vaccination (44, 64).

It should be noted that a controversy continues to the present day over the precise efficacy of BCG against adult pulmonary tuberculosis (69). Efficacy estimates range from 0% to approximately 80%. Less controversy exists in relation to consistent and appreciable protection against childhood TB and TB meningitis as confirmed by meta-analysis (77).

An increase in zoonotic diseases has often occurred during or after wars. During the American Civil War, glanders was widespread in the United States, especially in cities where large concentrations of horses were kept (22). It was a highly communicable disease in horses, mules and donkeys. Human infections have rarely or sporadically been reported, except in individuals whose occupations involved contact with animals. The disease has disappeared from most areas of the world (26). It was eradicated from the United States in 1934, largely due to efforts by local, state and federal veterinarians (63).

Yellow fever increased after the Spanish American War, but it was not recognised as a zoonotic disease until some 30 years later when Frederick L. Soper, PhD (1893-1977), an American epidemiologist and public health administrator, identified monkeys as the reservoir. Soper won a Lasker Award in 1946 for organising successful campaigns to eradicate yellow fever and malaria between 1927 and 1945 (46; James H. Steele, personal communication, February 2007).

World War I coincided with a global pandemic of influenza, a disease that is currently known to be related to an avian influenza virus. Today, we face a similar potential threat of another avian influenza pandemic if the specific avian influenza virus (A) H5N1 undergoes sufficient antigenic shift or mutation.

In 1945, at the end of World War II, Joseph Mountain, a physician and chief of the USPHS's Bureau of State Services met with James H. Steele to discuss the global origin and importance of zoonotic diseases. Mountain challenged Steele saying 'What are you veterinarians going to do for public health, now that the war is over?' As a result of this meeting, Steele organised a list of zoonotic diseases to promote veterinary public health and gained the cooperation of Bennett T. Simms, a veterinarian and Chief of the USDA's BAI (the true forerunner of the present Animal and Plant Health Inspection Service [APHIS] and the Food Safety and Inspection Service [FSIS]) along with Soper, the new director of the Pan American Health Organization (62, 65; James H. Steele, personal communication, February 2007). Soper believed that veterinary public health (VPH) should have a strong presence in the western hemisphere; the first project established a Zoonosis Center in Azul, Argentina, to deal with hydatid disease and to control rabies (16, 65; James H. Steele, personal communication, February 2007).

The World Health Organization (WHO) was created at a meeting organised by the United Nations under the guidance of Thomas Parran, Jr (1892-1968), a physician and Surgeon General of the United States from 1936 to 1948. The USPHS collated recommendations to be included in the work of the WHO. Among these recommendations was the importance of VPH. The latter was received and approved. The Public Health Organizing Committee of the United Nations issued a statement that recognised the importance of zoonotic diseases. In 1948, Martin M. Kaplan (1915-2004), a widely respected public health veterinarian, virologist and humanitarian, was recruited to organise a VPH programme in the WHO. His appointment led to the first meeting of the WHO Expert Committee on Zoonoses in 1950. Kaplan believed strongly that human health and animal health are closely associated. He believed that neither could prosper effectively without the other, especially in the developing world (5; James H. Steele, personal communication, February 2007).

The 'one medicine' concept was described and promoted in the 20th century book editions of *Veterinary medicine and human health*, by Calvin W. Schwabe (1927-2006), a renowned veterinary epidemiologist and parasitologist; he is also recognised as the leading philosopher of the veterinary profession (16). The 'one medicine' concept conforms to the vision and principles initially advocated by Virchow and adopted to a large extent by Osler and others. Schwabe proposed a unified human and veterinary approach against zoonotic diseases (16, 57, 58, 59).

In the 1967 Joint Food and Agriculture Organization (FAO)/WHO Expert Committee on Zoonoses more than 150 zoonoses were identified (19). By 2000, more than 200 diseases were occurring in humans and animals that were known to be transmitted mutually; their aetiologies included viruses, bacteria (along with rickettsiae and chlamydiae), fungi, protozoa and helminths as well as arthropods as modes of transmission (40). This represents recognition of and/or emergence of a greater than 30% increase of zoonotic diseases in the last third of the 20th century. With newer diagnostic and research tools in an exponentially expanding age of biotechnology, what will this number be during the 21st century and beyond?

In the joint FAO/WHO technical report in 1975, VPH was defined as 'the contributions to the physical, mental and social well-being of humans through an understanding and application of veterinary science'. In 1999, the WHO conference on veterinary public health and control of zoonoses in developing countries invited experts from a total of 18 industrialised countries, countries in transition and developing countries (56). Held in Teramo, Italy, the conference was expanded to include FAO collaboration with the World Organisation for Animal Health (OIE: Office International des Épizooties). 'The major purpose was to consider the contributions that VPH programmes could make to human health on a global basis, with a particular future emphasis on developing countries'. At the Teramo meeting, the consensus definition of VPH was replaced and updated with the following: 'a component of public health activities devoted to the application of professional skills, knowledge and resources to the protection and improvement of human health'. It was believed that this new definition would be more consistent with the original WHO definition of health and also with the values, goals and targets of the WHO vision, i.e., 'health for all in the 21st century'.

The view of the conference had clearly evolved to recognise VPH as a multidisciplinary approach involving veterinarians in governmental and non-governmental sectors and including other health scientists and professionals (and paraprofessionals) that treat, control and prevent diseases of animal origin. A team approach to problem-solving research, control programmes and communications was expressed as essential to 'ensure that veterinary (medical) contributions to the improvement of human health would be both significant and sustainable'.

Today, the USDA's FSIS enforces regulations promulgated under the Federal Meat Inspection Act (originally enacted in 1906) and the Poultry Products Inspection Act (originally enacted in 1957). This has significantly influenced consumer food safety protection and risk reduction of many potential foodborne illnesses caused by bacteria, including the four major organisms *Campylobacter*, *Salmonella*, *Listeria* and *Escherichia coli* 0157:H7, parasites and other contaminants. High-profile bioterrorism food safety threats include botulism, *Salmonella*, *E. coli* 0157:H7, *Shigella dysenteriae* type 1, Typhi (typhoid fever) and *Vibrio cholerae* (cholera). All of these agents and diseases are also the public health food safety responsibilities of USDA-FSIS veterinary medical inspectors (28, 37, 53, 54, 62).

Zoonotic diseases in the 21st century

Compared to non-zoonotic pathogens, zoonotic pathogens are twice as likely to be associated with newly discovered, emerging, human illnesses. Indeed, of all the infectious agents that infect humans, approximately 60% are zoonotic (68). The 1999 outbreak of West Nile virus in New York City was a perfect illustration of the challenges societies face in addressing zoonotic diseases. In this example, there were two simultaneous outbreaks: one in animals and one in humans. Establishing the viral link between these two outbreaks was largely due to the persistent efforts of a veterinary medical pathologist, Tracey McNamara, head pathologist at the Bronx Zoo (71). Addressing the challenges of zoonotic diseases requires greater communication and collaboration between veterinarians and physicians in areas beyond public health, including clinical practice and biomedical research.

There have been many other emerging zoonotic disease outbreaks, including the Nipah virus outbreak in Malaysia in 1998-1999, the severe acute respiratory syndrome (SARS) outbreak in 2003 and, most recently, the avian influenza (A) H5N1 outbreak that is spreading throughout Asia, Europe and Africa (33). Many of the agents of bioterrorism are zoonotic in origin (12, 13). In fact, five of the top six 'category A' disease agents designated as potential bioterror threats by the United States Centers for Disease Control and Prevention (CDC) are zoonoses. These are anthrax, botulism, plague, tularaemia and viral haemorrhagic fevers; smallpox is not classified as a zoonosis (24). Reasons for the emergence of these zoonotic disease outbreaks are multiple: human population pressures, intensive agricultural practices, consumption of bush meat, importing and dumping of used tires that serve as reservoirs for mosquito breeding, air travel and a global trade in exotic animals (24, 43). Since scientists have identified less than 1% of the viruses on the planet, it should be anticipated that many more zoonotic viral pathogens will 'emerge' (31).

Magnitude of the zoonotic disease challenge

Of the newly identified zoonotic pathogens, most are viruses, in particular, RNA viruses (23). The sheer magnitude of the numbers of viral particles that must be confronted is staggering. For example, it is estimated that the oceans alone contain somewhere around 4×10^{30} viruses (66). This number is greater than the number of stars in the observable universe.

One 35 ton gray whale has been estimated to excrete into the oceans over 10^{13} calicivirus particles in its faeces on a daily basis (61). This class of virus consists of four groups of which the noroviruses are the most significant human pathogens. These can infect humans and have been implicated in many cruise ship outbreaks.

Enormous numbers of viral particles can exist on land. For example, one duck can excrete billions of avian influenza (AI) virus particles (72). This high rate of excretion can result in billions of AI virus particles in water and the surrounding environment which could present an elevated exposure risk to domestic chickens and a lesser risk to humans (30).

Given the enormity of the numbers of emerging viruses as well as the growing challenges of drug-resistant bacteria, the medical and veterinary medical communities must work together to better understand and contain them. What is the current status of these collaborative efforts?

Current status of medical and veterinary medical collaboration

Unfortunately, the Virchow's, Osler's and other like-minded medical professionals in the world have largely disappeared. In the past decades, human and animal diseases have been treated as separate entities and physicians and veterinarians do not commonly communicate and/or collaborate with each other. There are a number of possible reasons for this situation.

First, there is a disproportionate number of accredited veterinary medical schools compared to accredited medical schools worldwide. This could affect the number of graduates who meet international professional standards. According to the AVMA, there are 39 accredited (by AVMA standards) colleges of veterinary medicine worldwide: 28 are in the United States (3). There are probably many more accredited foreign veterinary medical schools that would meet AVMA standards.

There are 125 accredited medical schools in the United States (M. Brownell Anderson, personal communication, November 2006). On a global scale, there were 1 931 medical schools operating in 172 countries as of 23 October 2006. These medical schools in different countries are recognised by their respective governments but do not necessarily meet each other's standards or those within the United States (20).

Second, in the area of clinical practice, medical schools do not typically emphasise the ecology of micro-organisms so medical students might not see the importance of zoonotic diseases and their impact on human health, and hence, the need to work with their veterinary medical colleagues. In schools of veterinary medicine, large animal curricula have traditionally emphasised the 'herd immunity' or 'herd health' concept. This policy tends to reinforce the same important principle related to humans contained within basic public health courses currently offered at schools of public health. Therefore, initially graduate veterinarians may have a wider scope for approaching and appreciating problems affecting human health epidemiology than graduates from medical schools.

The educational background for veterinarians provides training in basic biomedical and clinical sciences that is comparable to that of physicians. Unlike their human medicine counterparts, veterinarians must have multiple species knowledge and training that emphasises comparative medicine. Preventive medicine, population health, parasitology, zoonoses and epidemiology serve them well in public health careers. Historically and traditionally, the veterinary medical profession has held a focus on protecting and improving animal and human health (57, 65).

While collaborative efforts in the area of public health, as described in the beginning of this paper, have been considerable and must continue, there should be further collaboration in clinical and research settings.

Areas ripe for collaborative efforts

The clinical setting

The lack of emphasis on the importance of zoonotic diseases in medical schools might explain the findings by Grant and Olsen who studied the role of physicians and veterinarians in preventing zoonotic diseases in immunocompromised patients. They found that physicians were generally not comfortable discussing the role of animals in the transmission of zoonotic diseases. However, most of the patients did not view veterinarians as a source of information for human health (21). The end result is that few physicians or veterinarians advise their patients, or animal-owning clients, on these issues. Regardless, these health issues are very important – especially for individuals who are chronically immunosuppressed and rely on animals for either their livelihoods and/or for companionship.

The risks of pet ownership for chronically immunosuppressed pet owners are considerably greater than for the immuno-competent. For example, exposure to reptiles carries significant risk since virtually all reptiles carry *Salmonella* in their normal intestinal tract flora. In the United States, exposure to these animals has led to almost 100 000 cases of reptile-associated salmonellosis each year (10).

Of course, animals besides reptiles carry zoonotic risks. Some zoonotic diseases can come from common household pets, such as the domestic cat, which is the most commonly owned pet in the United States. The domestic cat is a major reservoir for *Bartonella henselae*, the causative agent of bacillary angiomatosis-peliosis in immunocompromised individuals and cat scratch disease in the immunocompetent (39, 67). More than 40 000 cases of cat scratch disease are reported in the United States each year. How the organism is transmitted from cats to humans is not fully understood, but fleas are thought to play a major role, in addition to scratches and bites (70).

Cats and dogs are the host species for the roundworms *Toxocara cati* and *Toxocara canis*, respectively (50). Children are usually infected through accidental ingestion of embryonated eggs although there have been reports of infections resulting from the ingestion of adult or sub-adult worms from infected cats and kittens (17). Depending on which tissues and organs have been invaded by the larvae, the clinical diseases known as visceral *larva migrans* (VLM) or ocular *larva migrans* (OLM) can occur (15). Geophagia, litter(s) of puppies or kittens in the home and race are some of the risk factors for acquiring *T. cati* and *T. canis* in pediatric populations (18, 25, 42).

Immunosuppressed humans and animals

Humans are not the only species that can become immunosuppressed. For example, dogs are treated with immunosuppressive drugs for canine atopic dermatitis, inflammatory bowel diseases, and immune-mediated haemolytic anaemias. Approximately 9% of dogs were diagnosed with atopic/allergic dermatitis, atopy, or allergy in a study of 31 484 dogs in 52 private veterinary medical practices in the United States (27, 41). The recommended treatment for this condition is oral antihistamines, glucocorticoids (usually most efficacious) or sometimes cyclosporine A in severe cases (49). Superficial bacterial infections, such as *Staphylococcus intermedius* and yeast infections like *Malassezia pachydermatitis*, commonly occur in dogs from their disease condition and/or their reduced immune function due to the treatment with glucocorticoids (14, 48). Inflammatory bowel disease and immune-mediated haemolytic anaemias in dogs are treated with immunosuppressant drugs, such as high-dose glucocorticoids, cyclosporine and azathioprine (1, 11, 74).

To date, there are no studies investigating the risk(s) immunosuppressed pets pose to their human owners. Theoretically, immuno-suppressed pets harbouring various pathogens could pose risks, especially if their owners are also immunosuppressed. Veterinarians would likely not know the immunological status of the owner of their animal patients before prescribing immunosuppressive drugs to their pets unless the owners volunteered the information.

Animals that should not be pets

Some animals should simply not be pets for people at risk because the danger of zoonotic disease transmission or the physical risks from animals that may bite or scratch is too great (9). Reptiles (e.g., pet turtles and snakes) are one example because the *Salmonella* in their intestinal tracts cannot be eradicated. Monkeys, particularly rhesus and cynomolgus macaques, should not be pets because of the risk of exposure to the deadly B virus. Monkeys also make poor pets because they are wild and frequently bite or scratch. Large wild carnivorous animals, such as tigers or bears, do not make good pets due to biting and mauling tendencies. Veterinarians and physicians could do much to improve public health by discouraging their pet-owning clients and patients, respectively, from owning them.

The risk of zoonotic disease transmission can be greatly reduced for some diseases from cats and dogs. Cats' fleas could be controlled to prevent transmission of *Bartonella henselae* (39). Similarly, dogs and cats should be regularly assessed and treated by a veterinarian for toxocariasis; this is commonly recommended by practising veterinarians when pets are presented for physical examinations. In addition, clients are routinely advised to submit stool samples at periodic intervals; obviously compliance is essential but not consistently forthcoming. Veterinarians and physicians should emphasise the importance of careful hand washing after handling animals as a significant disease preventive measure (55).

Occupational health

Occupational exposure to zoonotic pathogens also pose risks to human health. For example, *Streptococcus suis* can cause meningitis or occasionally fulminant sepsis in pig farmers, and *Campylobacter* infection is an occupational risk for packers in poultry factories; the *Campylobacter* organism is also identified as being a common cause of foodborne illness (7, 45, 51, 76).

While zoonotic disease risks in working with laboratory animals appear to be low, the results can be deadly for the few cases that occur (73). For example, rhesus and cynomolgus macaques, which are commonly used in biomedical research, frequently harbour B virus (Cercopithecine herpesvirus 1) (29). This virus causes no disease in its simian hosts but in humans the death rate from infection can exceed 70% if the exposed mucous membrane or wound is not properly washed promptly and treated with anti-viral medications as indicated.

Biomedical research

The global community critically needs more veterinarians to work in biomedical research, such as comparative medicine, which would increase our understanding of why and how diseases spread from species to species. The field of comparative medicine focuses on the anatomic, physiological, pharmacological, microbiological and pathophysiological processes across species – including humans. Comparative medicine includes the study of host-pathological agent interactions in infectious diseases and their pathogenesis which are so critical to our understanding of zoonotic agents.

There have been monumental achievements in comparative medicine in addition to the discovery of BCG tuberculosis vaccine. For example, in 1893, Smith and Kilborne (the BAI physician and veterinarian mentioned previously) published a paper establishing that an infectious agent, *Babesia bigemina*, the cause of cattle fever, was transmitted by ticks. Their seminal work helped set the stage for Walter Reed's discovery of yellow fever transmission via mosquitoes. Recently, a physician-veterinarian team contributed to health care for humans and animals when Rolf M. Zinkernagel, a physician from Switzerland and Peter C. Doherty, a veterinarian from Queensland, Australia, discovered how the body's immune system distinguishes normal cells from virus-infected cells. For this they shared the Nobel Prize in 1996 (32, 34, 35, 36).

The United States veterinary medical community supports the 'one medicine' concept. However, until recently they have been generally lackadaisical regarding strong efforts to engage in active dialogue and promotion of the concept among themselves and much less towards the physician community. The current AVMA President, Roger K. Mahr endorsed a 'one health', i.e. 'one medicine' initiative before the AVMA house of delegates in Hawaii in July 2006, prior to assuming the presidency (60). The commitment, efficacy and continuance of this activist effort beyond the yearly AVMA presidential term remain to be seen.

The international veterinary medical and medical communities could do much to promote this concept worldwide by actively encouraging joint efforts in biomedical research. For example, the CDC recognises the veterinary medical responsibilities in biomedical research along with ecosystem management, public health, food and agricultural systems, care of companion animals, wildlife, exotic animals and food animals. Veterinarians at the CDC are assuming expanded roles; this reflects an appreciation of the variety of their capabilities and the contributions that they make (38). Strong evidence of the expanded participation of veterinarians at the CDC was the CDC's visionary creation of a National Center for zoonotic, vector-borne and enteric diseases in 2006 and 2007 under the leadership of Lonnie J. King, a veterinarian. King is a prominent administrator, educator and public health leader. He previously served as Administrator of APHIS and Dean of the Michigan State University, College of veterinary medicine.

Establishing collaborative efforts

In the clinical setting, veterinarian/physician collaborations would be important for chronically immunosuppressed individuals. An immunosuppressed individual may benefit greatly by having both his/her physician and veterinarian keep close tabs on potential zoonotic disease risks. For example, physicians should encourage their immunosuppressed patients to have their pets undergo regular checkups to help ensure that preventable zoonotic diseases are promptly diagnosed and treated.

There should be increased and diverse communications between physicians and veterinarians regarding human and wildlife health. For instance, veterinarians should develop relationships with local hospital epidemiologists and state health department epidemiologists so that if large wildlife die-offs are observed, as occurred during the West Nile virus outbreak in New York City, veterinarians would feel comfortable about promptly notifying their physician and public health colleagues to be on the alert for possible human involvement (71). This expedited direct communication between veterinarians and physician/veterinarian epidemiologists (viz. local and/or state) could help ensure more rapid responses, especially in areas in which local public health departments either do not exist or are not involved in zoonotic disease surveillance and response.

New ties and opportunities for collaborative, cooperative and coordinated efforts could be achieved by jointly sponsored veterinary medical and human medical conferences on zoonotic disease risks through their respective local and state organisations. Clinical studies to assess whether immunosuppressed pets pose increased zoonotic disease risks to their owners, especially to those who are immunosuppressed themselves, could be another area of liaison.

Conclusion

The 'one medicine' concept has languished far too long in the modern milieu of clinical care, public health and biomedical research. It is or should be an obvious and essential catalyst for 'jump starting' present and future medical advances in human society.

Civilization is facing a multitude of threats, not the least of which is potential bioterrorism utilising destructive microbial agents. Most of these agents are zoonotic by definition. Only by using the combined, synergistic creativity, genius and talents of physicians and veterinarians, can many unsolved mysteries of the basic sciences, epidemiology, pathogenesis, prevention, control and therapeutic cures be unravelled expeditiously. Millions of human and animal lives hang in the balance.

It is incumbent upon and indeed the duty of enlightened veterinarians and physicians (and their respective professional organisations) to alert, explain and educate the world's medical, veterinary medical, public health, research, academic, political, governmental and news media communities – and the general public – about this critically unique tool available to combat the health crises of our time. Instituting 'one medicine' would help significantly to modify or possibly avert many crises.

An appropriate analogy to continued disregard of this dynamic mechanism for expeditious expansion of health care modalities can be taken from an event that occurred prior to World War II when Winston Churchill persistently lamented failure to recognise and deal with the Nazi threat. He occasionally cited the poem:

Who is in charge of the clattering train?
The axles creak and the couplings strain,
And the pace is hot, and the points are near,
And Sleep has deadened the driver's ear;
And the signals flash through the night in vain,
For Death is in charge of the clattering train.

Conflict of interest

The authors have no conflict of interest or financial investments to disclose.

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