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Diseases, dilemmas, decisions—Converting epidemiological dilemmas into successful disease control decisions

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ABSTRACT

This paper describes 50 years of personal experience in dealing with a range of animal and zoonotic diseases at national and global level, using a series of selected examples to illustrate both the nature of the various dilemmas and difficulties faced, and the way in which they were solved using the tools and techniques that were available at the particular time. A major theme throughout has been the dependence on advancing computer technology, which initially allowed only simple analyses and modelling activities to be undertaken, but as computers have grown increasingly powerful, techniques such as Bayesian spatial regression have become available to the epidemiologist, making possible forms of analysis and disease modelling which had been mere dreams in earlier decades.

There is now a need to integrate these tools and techniques into a toolbox which allows both epidemiological and economic analysis to be applied to virtually any type of disease, thereby further extending the capacity of epidemiologists to solve even more difficult problems in the future.

1. Introduction

Over the course of 50 years involvement in applying epidemiological methods to solve complex disease control problems, I have watched the field of veterinary epidemiology and economics evolve from one where there were very few advanced tools and we relied heavily on our ability to observe and to think our way through problems, to the current situation where our toolbox is full of powerful techniques, but we still need to search for epidemiological insights and avoid the temptation to just crunch the numbers and believe the result must always be right. In this paper I draw on a chronological sequence of selected challenging disease situations in which I was involved as an epidemiologist, to illustrate the evolution of approach which occurred as we explored different ways of solving epidemiological problems, and how the combination of increasingly sharp tools and sharp thinking jointly provided the key to converting some very difficult epidemiological dilemmas into sound disease control decisions. This paper is a description of parts of my epidemiological journey, on which I have been accompanied by many excellent people, most of whom cannot be named in the text without losing focus on the subject, but most of them appear in the bibliography as co-authors. It is therefore, a personal perspective on a shared journey, a rare opportunity to look back on 50 years of disease control, and pass on some of the lessons I have learned.

2. The legacy of Calvin Schwabe

I had the good fortune to have several contacts with Cal Schwabe from 1969 onwards, and to gain the benefit of his vision and epidemiological ingenuity. Through this paper, I would like to recognise the extent of his contribution to our field. He was a leader in identifying and pursuing opportunities where epidemiologists could make a global contribution, and he was supportive of many younger colleagues in these efforts. In 1974, he was Chairman of the WHO/FAO/OIE Expert Committee on Veterinary Public Health, where under his leadership we laid out through the Report a vision of what has subsequently become widely known as one health. Although I was only 30 at the time and half the average age of the Committee members, he invited me to be the Rapporteur of the Committee, which meant we worked closely together on finalising the text of the report and subsequently pursuing its implementation. This gave me valuable exposure to his thinking and approach to achieving progress. He was also able to pick up

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new techniques and research opportunities from diverse sources, and I subsequently applied a number of the techniques I learned from him. I am therefore, very honoured to present the 2014 Calvin W. Schwabe Symposium address, honouring his contribution and demonstrating how I have applied similar thinking over my career of 50 years.

3. The contribution of John Wilesmith

I would also like to use this opportunity to recognise the very major contribution which John Wilesmith has made to epidemiology and particularly to successfully managing a series of very difficult disease dilemmas. Over the course of his career in the British government, John faced and dealt effectively with more epidemics and outbreaks than any epidemiologist should have to do, and his success in unravelling the epidemiological complexities of a number of major diseases deserves the highest praise. I collect epidemic datasets like other people collect stamps, and Britain has provided me with the outstanding gems in my collection. John has been very kind over many decades in offering me the opportunity to work with the datasets which he and Judi Ryan had built for each of the different diseases they worked on together. We have spent many hours together debating the interpretation of epidemiological evidence, and working out ways of answering epidemiological dilemmas. Some of these are illustrated in the examples below. John's greatest challenge and achievement was to identify the true cause of bovine spongiform encephalopathy (BSE), and guide Britain through to successful control of this disease, despite the endless supply of people who believed they knew better.

4. Core principles of epidemiological investigation

As I review 50 years of involvement in epidemiology, working with a long list of diseases in a variety of countries, I consider there are a few key factors which are influential on success in understanding and then controlling any particular disease.

1. Formulate all realistic epidemiological hypotheses and structures of the putative causal web for the disease, then progressively rule them out by evidence or experiment, including extensive use of thought experiments. While this seems self-evident, far too often people narrow the options too quickly into a preferred hypothesis and focus their efforts on proving this rather than disproving the alternatives.
2. Success comes from clarifying the framework of the causal web and hence understanding the underlying epidemiological pattern (even if imperfectly), rather than understanding specific individual processes more precisely, but failing to identify the weak points in the web, which facilitate control.
3. Having clarified the final causal model, identify as many intervention points as are realistic to apply, and design a robust and economically appropriate control strategy which is resistant to epidemiological uncertainties and unexpected developments.
4. Implement the chosen control strategy in ways which allow early experience to guide progressive adjustments.
5. Monitor progress using epidemiologically insightful surveillance procedures, and adjust the control strategy in the light of findings from the surveillance.
6. Be open to new information which may require a change in strategy, even if the information is unwelcome.

There is nothing novel about these points, other than the fact that far too often they are disregarded. In the following series of examples, I will bring out both successes and failures in resolving epidemiological dilemmas, and the critical importance of well designed investigations and analyses.

5. Bovine brucellosis

In the 1970s, Australia began a national brucellosis and tuberculosis eradication program. Both components succeeded, with Australia being declared free of bovine brucellosis in 1989, ahead of the expected date. It was a very expensive program, and the opportunity was taken to apply a number of epidemiological initiatives, particularly with regard to brucellosis eradication.

Up to that time, most data used in disease eradication programs was stored manually, or by the 1960s and 1970s records were stored on mainframe computers, with little or no direct access to the records by field staff responsible for the program. The decision was made to develop a novel approach for the Australian eradication program, and Dr Dick Roe Rob Cannon and I developed the Australian National Animal Disease Information System (ANADIS). This operated from 1977 on 18 minicomputers located at veterinary laboratories throughout the country, with a 19th at the national centre in Canberra, where we were based. Each computer had kB of memory, with the central computer having the luxury of kB. Hence programming had to be extremely efficient to process enormous numbers of records with such limited memory and very slow processors.

The focus of ANADIS was on providing an epidemiologically dynamic set of support services and management tools at the local level. Field staff entered data at each of the regional sites, and produced reports immediately. Very few people who used the computers had ever personally interacted with a computer before this. Integration of the system was by mailing of 8 in diskettes weekly from each laboratory to Canberra and back – making a true national distributed system in the best way possible in the 1970s. Key initiatives in the system were the authority given to field staff at local level to manage their part of the program and to analyse local data using epidemiological methods which were built into the software, while allowing national staff to monitor and evaluate progress across the country, and to solve problems as they arose. Rather than being a simple data repository, the whole system was designed to capture the epidemiological dynamics of the disease eradication program and allow monitoring of progress and detection of problems (Roe, 1979; Sykes, 1982; Andrews, 1988; Cannon, 1993). Because the system made extensive use of abattoir testing for brucellosis, the first key development was the implementation of unique property identification codes for all properties in the country, with each code including a check character. This is calculated when the code is established, such that it makes the entire code exactly divisible by 11, having converted letters to a numerical value. This system virtually requires local computer access so that errors can be corrected immediately, since the computer analyses all codes at data entry and reports incorrect codes. Early in the program the number of incorrect codes detected was worryingly high and very variable between locations (since all failed entries were stored and reported to Canberra), but as staff became familiar with the system the error rate dropped to a very low level. This simple system avoided large amounts of wasteful testing which would otherwise result from incorrect allocation of test results to a particular herd. All cattle sent for slaughter from a property were required to carry a tail tag with the code, and this tag accompanied the blood sample through the testing system.

The second important development was the establishment of a standardised classification system for herds based on their brucellosis test results, which could be accurately represented in computer code. Herds went through a sequence of steps in which infection was eliminated (if initially present), and freedom was

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