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Virtual surveillance of communicable diseases: a 20-year experience in France

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Inserm has developed, since 1984, an information system based on a computer network of physicians in France. It allows for constitution of large databases on diseases, with individual description of cases, and to explore some aspects of the mathematical theory of communicable diseases. We developed user-friendly interfaces for remote data entry and GIS tools providing real-time atlas of the epidemiologic situation in any location. The continuous and ongoing surveillance network is constituted of about 1200 sentinel voluntary and unpaid investigators. We studied their motivation, reasons for either withdrawal or compliance using survival analyses. We implemented early warning systems for outbreak detection and for time–space forecasting. We conducted epidemiological surveys for investigating outbreaks. Large available time and space series allowed us to calibrate and explore synchronism of influenza epidemics, to test the assumption of panmixing in susceptibles-infectious-removed type models and to study the role of closing school in influenza morbidity and mortality in elderly. More than 250 000 cases of influenza, 150 000 cases of acute diarrheas, 35 000 patients for whom HIV tests have been prescribed by general practitioners and 25 000 cases of chickenpox have been collected. Detection of regional influenza or acute diarrhea outbreaks and forecasting of epidemic trends three weeks ahead are currently broadcasted to the French media and published on *Sentiweb*© on a weekly basis. Age–cohort–period models assessed field effectiveness of mass immunization strategies against measles and influenza in the country. Case–control studies with more than 1200 sets of cases of acute diarrheas and their matched controls showed the role of calicivirus and rotavirus as probable major causes of gastroenteritis during recurrent widespread outbreaks in winter in France. An age-specific model for chickenpox showed the probable role of children in disease transmission to their susceptible parents or grandparents. High level of synchronism between influenza epidemics has been demonstrated, either at a regional level (in France) or between France and the USA. The designation of our lab as a WHO collaborating center for electronic disease surveillance stimulates the development of global monitoring of diseases. We developed operational systems that are now available for the global monitoring of influenza (FluNet©), and human and animal rabies (RABNET©). Extension of electronic syndromic surveillance is needed in the world for improving surveillance capacities and real-time response against emerging diseases.

1 Introduction

Disease surveillance provides essential information for control and response planning, helping to identify changes in incidence and affected groups, thereby providing valuable additional time for public health interventions. Syndromic surveillance aims to use health

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and health-related data that precede diagnosis and/or confirmation to identify possible outbreaks, mobilize a rapid response and thereby reduce morbidity and mortality. This approach is increasingly being explored by public health officials to detect any emerging event (eg bioterrorist attacks) and for routine surveillance.[1–6] When teleinformatics was introduced in public health fields, 15 years ago, the potential of its use as a rapid and early warning system was highlighted by local experiences. When France developed its sentinel system,[1,2] New York State implemented HEALTHCOM,[3] the CDC set up an electronic network between State's department in charge of health.[4] Simultaneously, relational database system grew rapidly, and allowed for exploring huge fluxes of information. The client–server architecture allowed for a rapid remote access, opening several simultaneous sessions on a unique application. With the Internet, health information is nowadays available for any public health professional, the world-wide public and the media. Whereas political implication of releasing sensitive and complex information on the web without any access restriction has not been totally solved, confidentiality issues are probably partially solved using aggregated data (eg incidence rates) without any patient identification. A higher level of standardization and harmonization remains urgent to allow international comparisons of real-time indicators of morbidity or mortality.

2 The French sentinel experience

France probably took a technological step forward in electronic disease surveillance, thanks to a national telecom program which delivered to French citizens free of charge in 1983 videotext home terminals. In 1984, Inserm (The National Institute of Health and Medical Research in France) in collaboration with the Ministry of Health developed electronic monitoring of communicable diseases. A sample of 1193 out of the 60 000 French voluntary general practitioners (GPs) remotely enter reports on 12 conditions on a weekly basis. Sentinel GPs update a web-accessible database with information on diseases under surveillance. Weekly national and regional ongoing disease incidence estimates are published on the web (http://www.sentiweb.org). The ongoing surveillance follows the weekly protocol on influenza-like illness, acute diarrheas, chickenpox, zoster, measles, mumps, hepatitis A or B, male urethritis, asthma attacks, suicide attempts and GPs referral to hospital. The whole network is regularly asked to participate in epidemiological studies (eg panic attacks, depression, chronic bronchitis, Alzheimer disease). The network itself is also a research object: it is monitored in terms of activity, participation, 'survival'. It clearly shows (Figures 1–4) that GPs may connect to the host computer for an average of 5 min per connection at any time in the day, seven days a week. It deserves specific studies, such as studies on GPs risk perception.

Other sentinel systems have been set up in Europe on a similar basis.[5,6] Our experience is that the most difficult task is to maintain a high level of motivation and participation among the voluntary and unpaid GPs. But it is still more difficult to try to recruit new sentinel GPs than to try to keep the enrolled ones. After having published 40 full pages in a daily medical newspaper (*Le Quotidien du Médecin*), we only recruited 50 new GPs in 1998–99. In the same period, we experimentally investigated the efficacy of reminders of physicians during an epidemiological study. We sent a questionnaire on herpes zoster to

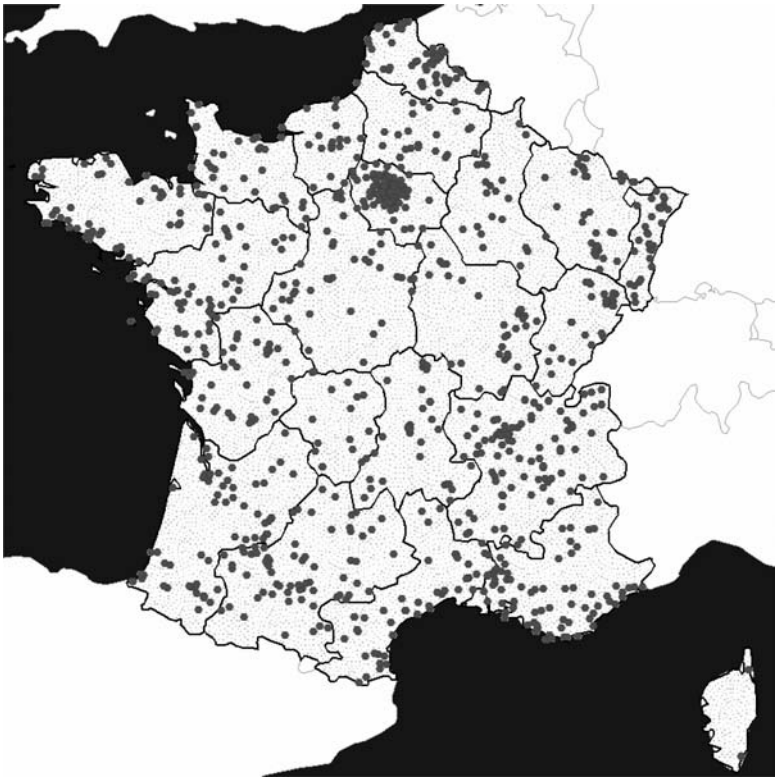

Figure 1 Geographical distribution of sentinel GPs in France ($n = 1193$ by January 2005).

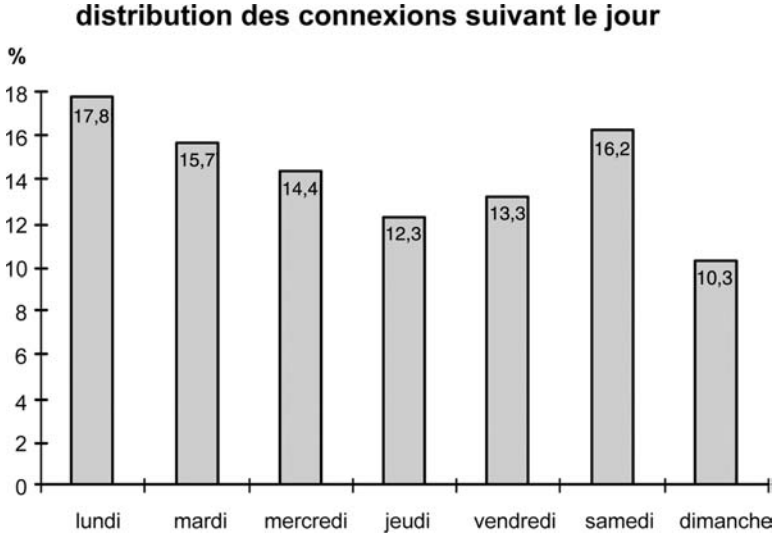

Figure 2 Weekly distribution of GPs connections to the host server ($n = 150\,000$ connections).

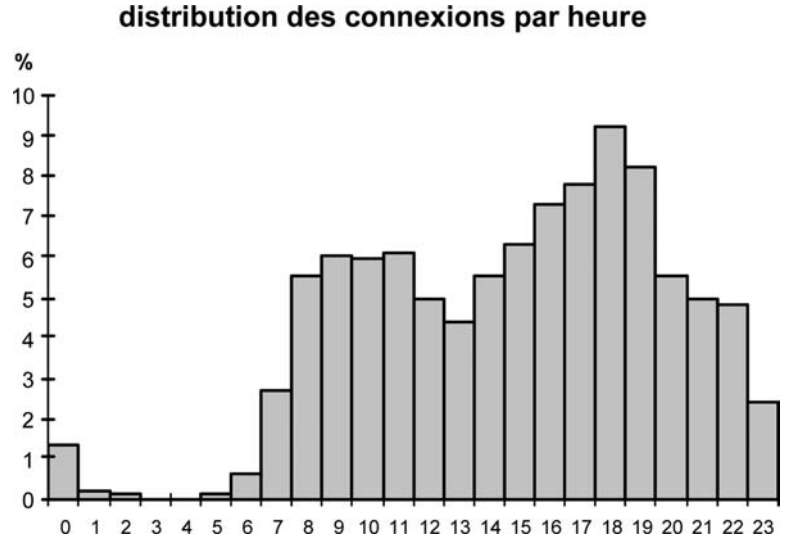

Figure 3 Daily distribution of connections to the host ($n = 150\,000$ connections).

the 1368 GPs in February 1999. The physicians were randomly assigned into three arms. In the first arm where no reminder procedure was implemented (ie the control group), only 38% of the physicians responded. In the second arm, in which one letter was sent to each non-respondent GP to the questionnaire, the response rate was eventually 57%. In the third arm, in which a phone call was personally made to the non-respondents, the response rate was 69% ($P < 000.1$). We also investigated the reason why GPs 'survived' in the network. According to the two following definitions a 'death' was defined either as a lack of connection for more than 12 days for more than 4 consecutive periods in a

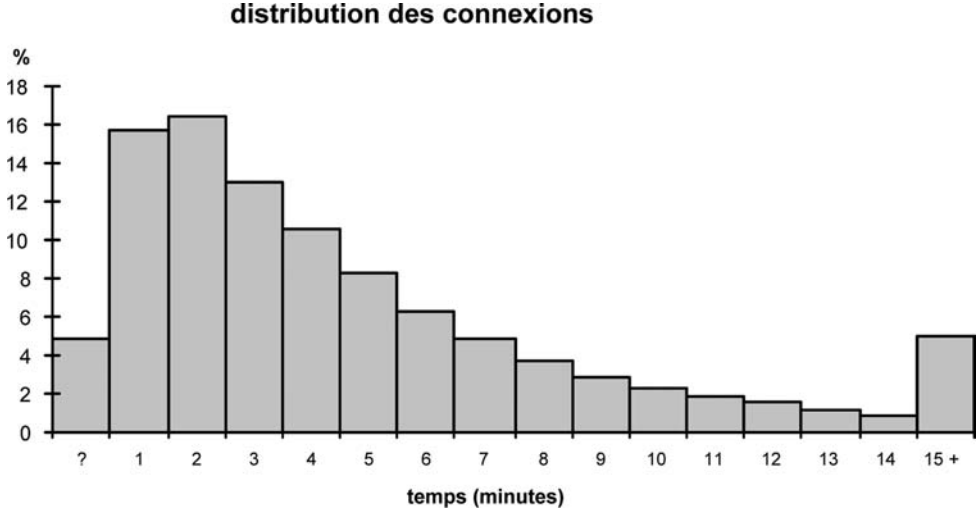

Figure 4 Duration of sentinel connection to the videotext home terminal system ($n = 150\,000$ connections).

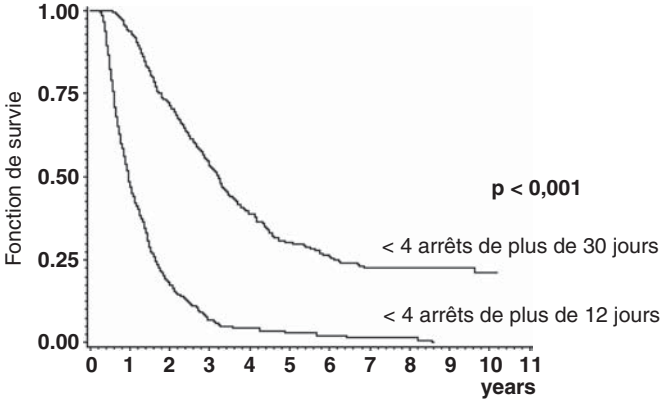

Figure 5 Compliance of sentinel GPs according to two theoretical protocols. [See reference 16]

year, or 30 days for more than 4 periods. The survival median time was, respectively, 11.7 months and 38.8 months (Figure 5). Independent predictive factors to a good compliance were investigated with a Cox model. Having less than 5 years, or more than 20 years, of practice and expressing a high interest in epidemiologic studies, were predictive of good compliance, whereas participation in competitive studies (ie studies not performed by our unit) was predictive of a short survival.

3 Research in user-friendly information systems

A study conducted in USA in 1997[7] has shown that 43% of American citizens aged 18 or over who had Internet access in the last 12 months used it for getting information on health. In 1998, 10 000 medical web sites were referenced. They were developed either by public or private institutions, from collective or individual enterprises. They varied greatly in quality.[3] In communicable diseases, the use of the Internet between states, countries and international organizations contribute to standardization and harmonization of the data collection (eg reporting period, shared thesaurus). Preventive measures decided on the basis of internationally acquired data may have a considerable impact on health and economics. For example, the massive exchange of information on AIDS contributes to the proposal of preventive measures. It also allows for rejecting or blaming at an international level scientifically unacceptable measures such as the frontier HIV control. The aim of global monitoring of influenza is to help decision-making in case of a new pandemic. By following the time and space dynamics of an influenza strain, it will also be possible to assess decisions on adopting preventive measures (eg closing schools, mass immunization, use of antivirals, and so on). This international cooperation in public health fields will most probably be considerably reinforced in the future. Early warning systems will be implemented in other international communicable diseases such as dengue, malaria, brucellosis, cholera. Database linkage with environmental information will be facilitated, allowing for the evaluation of the role of climate change, or pollution involvement in disease.

On the French sentinel system, information feedback is organized as a platform allowing for data query (Sentiweb,[8] http://www.sentiweb.org). The interface is user-friendly in the sense that any end-user may explore the database without any computer language or without any SQL programming. It is possible to download maps, time-series or tables of figures on any of the conditions monitored by the sentinel GPs since 1984. The database is updated weekly and contains the whole series without any interruption in time or space location. Maps are built 'on-the-fly,' therefore, nothing is stored into the MySQL 5 database except the raw data. The site is received with more than 200 000 hits a month. In France, media (newspapers and TV channels) download the maps during epidemic periods, and any Internet user has a free access without any restriction. To help the user avoid misunderstanding of the data, the site provides a weekly epidemiological bulletin (bilingual) and e-mail addresses of any of the members of our team (Figure 6).

A secured access has been made available allowing remote data entry by sentinel physicians. The physicians may at any time choose to use either the Internet or the videotext terminal. In 1999, about 15% of the sentinel physicians routinely used the Internet access, 85% still preferred to use the videotext home terminal delivered by the French Telecom (with a free phone number). In 2003, the videotext terminal was abandoned definitively.

This site follows the current requirements in France on confidentiality in information systems.

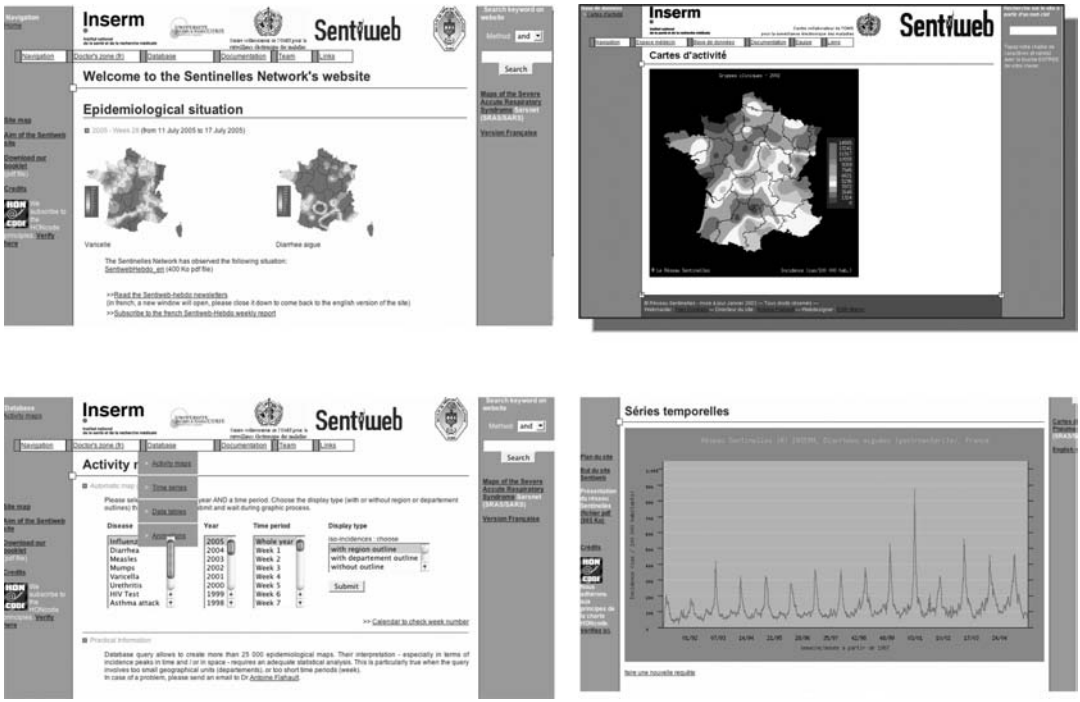

Figure 6 Sentiweb – http://www.sentiweb.org. A database on MySQL 5, accessible using PHP 5 language under the Linux (Mandrake) operating system on PC.

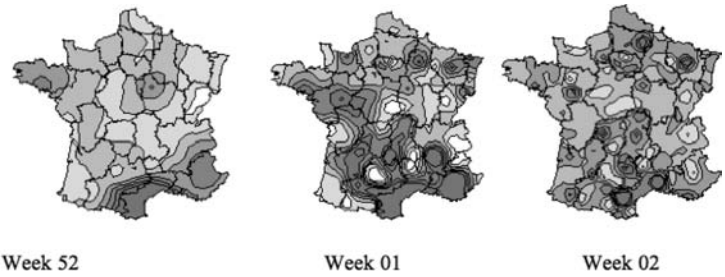

Figure 7 Time and space dynamic of acute diarrheas in winter in France.
Source: From Flahault et al., 1995.[10]

4 A platform for research in community epidemiology

Sentinel physicians have captured epidemiological data on the whole country since 1984. They have constituted large series on frequent conditions. Not only communicable diseases such as acute diarrheas are under surveillance, (Figure 7) but also asthma attacks and suicide attempts or hospital referral for any reasons. Acute diarrheas or influenza have been subject to particular involvement in epidemiological research by our team. Three case–control studies have been recently[9] conducted, including more than 1200 pairs of cases of acute diarrheas and their matched controls. The last one was performed in the winter of 1999, from stool samples collected in 150 cases and 46 controls. It identified the probable role of caliciviruses (RT-PCR) and rotaviruses A (ELISA), with an etiologic fraction of about 40% (only one virus – a rotavirus A – was found in controls).

Methods for assessing the quality of a syndromic surveillance system have been proposed. In particular, they require a precise assessment of the quality of the system in terms of its capacity to detect outbreaks appropriately. The French Sentinel Network (FSN) has monitored Influenza-like-illness (ILI) activity in France with the same methodology since 1984. For 21 years, during each winter, an influenza epidemic has been detected by the two French national influenza centers (based in Lyon and Paris), on the basis of virus isolation, and simultaneously by the FSN. The latter has therefore shown a high sensitivity to detect national influenza epidemics.

5 Towards a global disease monitoring

Global monitoring of disease arose rapidly.[11] First experiments were electronic list of E-mails, chats and forums, as the ProMED lists, allowing for the exchange of information before its validation.[12] There is an urgent need for systems that allow for remote data collection, real-time analysis and information redistribution. The Internet is the most appropriate tool responding to these requirements. With satellite channels for data transmission, these systems will be usable in case of disaster, wars or in any situation where surface communications are not available.[13] Some attempts have been proposed by the CDC in USA, in particular, antimicrobial resistance monitoring, linking labs to clinical data and a better usage of antibiotics.[14]

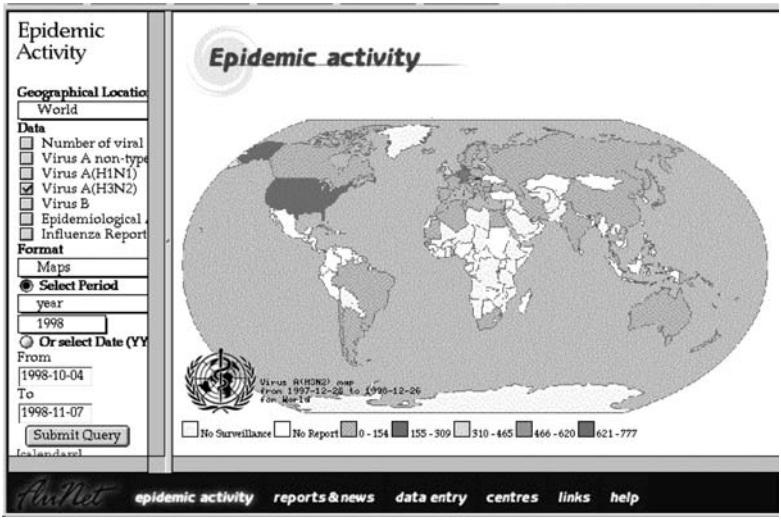

Figure 8 FluNet, a Global monitoring of influenza on the web (from 1997 transferred on the WHO website on http://www.who.int). This map has been obtained on-the-fly. It shows the dynamic spread of influenza virus type A/H3N2 in a specific time frame. By clicking in a region, we get a zoom, with additional information entered by the national influenza centers.

Recent efforts have been made in a collaboration between Inserm and WHO-HQ (Geneva). FluNet allows remote data entry by the 110 National Influenza Centers all over the world, and the 4 WHO collaborating centers for influenza. It also allows any Internet user to know on a real-time basis the global epidemiological situation of influenza. Maps (animated or not), charts and raw data are distributed on the web without any access restriction since 1997[15] (Figure 8).

A similar program has been set up for the global monitoring of human and animal rabies (RABNET). The 10-year epidemiology of rabies is available on the web, updated on a yearly basis. While the monitoring of antimicrobial resistance (including TB) is ongoing (named ARInfoBank), plans have been made for the surveillance of dengue and malaria.

6 Conclusion

Information system that allow a global disease monitoring will be increasingly available for many conditions. They will be used by the practitioners, helping them in decision-making (eg in travel medicine). Interested Public and the media will ask to obtain these information without any access restriction. These tools will provide health authorities with early warning systems, particularly when these data will be linked with other geographic information (eg remote sensing, surface variables, environmental factors).

References

1 Valleron AJ, Bouvet E, Garnerin PH., Menares J, Heard I, Letrait S, Lefaucheux J. A computer network for the surveillance of communicable diseases: the French experiment. *American Journal of Public Health* 1986; **76**: 1289–92.

2 Fourquet F, Drucker J. Communicable disease surveillance: the Sentinel network. *Lancet* 1997; **349**: 794–5.

3 Parsons DF, Garnerin P, Flahault A, Gotham I. The status of electronic reporting of notifiable conditions in USA and France. *Telemedecine Journal* 1996; **2**: 273–84.

4 Halperin W, Baker EL, Monson RR. *Public health surveillance*. Van Nostrand Reinhold, 1992: 238 pp.

5 Van Loock F. Infectious disease surveillance: early warning systems and public health interventions in a Belgian and European perspective. *Acta Clinica Belgica* 1994; **49**: 236–42.

6 Szecsenyi J, Uphoff-H, Ley-S, Brede HD. Influenza surveillance: experiences from establishing a sentinel surveillance system in Germany. *Journal of Epidemiology and Community Health* 1995; **49S**: 9–13.

7 Ferguson T. Digital doctoring – Opportunities and challenges in electronic patient–physician communication. *JAMA* 1998; **280**: 1361–2.

8 Boussard E, Flahault A, Vibert JF, Valleron AJ. Sentiweb: French communicable disease surveillance on the World Wide Web. *BMJ* 1996; **313**: 1381–2.

9 Letrilliart L, Desenclos JC, Flahault A. Risk factors for winter outbreak of acute diarrhoea in France: case–control study. *BMJ* 1997; **315**: 1645–9.

10 Flahault A, Garnerin P, Chauvin P, Farran, N, Saidi Y, Diaz C, Toubiana L, Drucker J, Valleron AJ, Sentinelle traces of an epidemic of acute gastroenteritis in France. *Lancet* 1995; **346**: 162–3.

11 Larkin M. Influenza information spreads across the web. *Lancet* 1999; **353**: 6736.

12 Morse SS, Rosenberg BH, Woodall J. ProMED global monitoring of emerging diseases: design for a demonstration program. *Health Policy* 1996; **38**: 135–53.

13 Garshnek V, Burkle FM. Application of telemedecine and telecommunications to disaster medicine. Historical and future perspectives. *JAMIA* 1999; **6**: 26–37.

14 Jernigan DB, Cetron MS, Breiman RF. Minimizing the impact of drug-resistant *Streptococcus pneumoniae* (DRSP). A strategy from the DRSP Working Group. *JAMA* 1996; **275**: 206–9.

15 Flahault A, Dias Ferrao V, Chaberty P, Esteves K, Valleron AJ, Lavanchy D. FluNet as a tool for global monitoring of influenza on the Web. *JAMA* 1998; **280**: 1330–2.

16 Chauvin P and Vallerou AJ. Participation of French general Practitioners in public health surveillance: a multidisciplinary approach. *J Epidemiol Community Health* 1998; **52** Suppl. 1: 25–85.