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Severe Acute Respiratory Syndrome: Analysis of a Successful Containment

SARS, a human infection caused by a coronavirus, is considered to be the first severe infectious disease to emerge in the twenty-first century that poses a serious threat to global health security, the livelihood of populations, the functioning of health systems, and the stability and growth of economies. (32) Its outbreak and rapid international spread through Asia, North America, and Europe in 2003 represented major challenges for people's health, economies, and international trade.

The outbreak took place from November 2002 to July 2003, and led to 8,096 cases and 774 deaths in 29 countries and regions, with an overall case-fatality ratio[1] of 9.6%. (33) When WHO alerted the world about SARS on March 12, 2003, there was still substantial uncertainty about the disease. Its cause and how it had developed were unknown, treatments were ineffective, and tests for all known causes of respiratory illness turned up negative. (34 p. 49) In various Asian hospitals, people who were dying from this mysterious disease presented similar symptoms, confirming fears of a worldwide spread of the disease that could have a devastating human, social, and economic impact.

The SARS outbreak occurred in an international context of growing concern about infectious diseases as a resurgent public health issue. Several infectious disease outbreaks, such as cholera in South America in 1991, pneumonic plague in India in 1994, and Ebola hemorrhagic fever in Africa in 1995, had demonstrated the need for stronger international cooperation in forming and implementing responses and in sharing the latest accurate information during the course of the outbreak in a timely way. (35 p. 92) In 1996, WHO began setting up a new emerging infectious disease program to better detect and respond to such outbreaks.

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(36) This initiative resulted in the establishment in 1999 of the Global Public Health Intelligence Network (GPHIN),[2] which scanned newsfeeds in English and French, and in the launch in 2000 of the Global Outbreak Alert and Response Network (GOARN),[3] which brought together some 120 partners.

Over the course of a few months, the world was put on alert regarding this new disease, which many observers feared would become a pandemic with a severe economic and social impact. Although the total number of fatal cases remained low in comparison, for example, to the 3.7 million estimated deaths from respiratory diseases and the 2.8 million estimated number of deaths from HIV/AIDS in 2003, (39 pp. 154–158) the special features of SARS made it a global public health risk. First, its spread from person to person required no specific vector. Second, it incubated silently for about one week and presented the symptoms of many other diseases, particularly endangering hospital staff. Finally, it killed about 10% of those infected. These features meant that the disease could spread easily along the routes of international air travel, placing every city with an international airport at risk from imported cases (40).

According to some authors, the perception of risk of a SARS pandemic resulted in a disproportionate economic impact. Nevertheless, the necessity of contending with SARS was considered an historic moment in the governance of risks of global infectious disease. (41 p. 7) The effort represented the first successful management of an emerging infectious disease in globalized societies and economies of the twenty-first century.

2.1 SARS risk analysis

The account of the SARS story brings into focus several aspects of the performance of a risk analysis by WHO. WHO verified information about possible outbreaks of a new disease, activated an influenza surveillance network that could perform laboratory tests, led field investigations early in the process (except in China) to learn about the cases being detected in affected areas, and evaluated these results and the regional and then the international spread of the disease in order to issue recommendations. Estimates of the SARS risk were based on qualitative elements, for the probability of risk and the consequences could not be precisely quantified given the high level of uncertainty. This initial assessment was done in the context of nearly complete ignorance about the disease, so that fear of an influenza pandemic led to the global alert of March 12 and March 15, 2003. This alert was followed by a series of measures designed to acquire knowledge about the virology, epidemiology, and clinical aspects of the disease and pursue the risk assessment during the SARS crisis.

2.1.1 Method and legitimacy

WHO used a risk assessment method that was developed prior to the SARS case and adapted it to the specificities of the disease. In parallel, WHO gained legitimacy for its actions by issuing recommendations that were largely followed and validated later in the process by the World Health Assembly.

2.1.1.1 Risk assessment method

WHO developed risk assessment methods that could be used jointly to address SARS at different levels: at the organizational level in assessing the public health event and leading the scientific assessment of the disease, at country levels in improving national public health policies, and at the disease level in formulating guidelines to be used as standard protocols for known diseases. WHO's risk assessment of SARS was based on consistently combining its overall risk assessment framework, its alert and response method, and elements of the influenza plan of 1999. In the case of an outbreak of an infectious disease, the alert-and-response method, in compliance with the overall risk assessment framework, focuses on assessing the infectious nature of the disease and therefore its potential to spread internationally, taking into account the need to effectively cope with the disease as quickly as possible.

In its World Health Report 2002, "Reducing Risks, Promoting Healthy Life," (26 p. 8), the organization defines risk as "a probability of an adverse outcome, or a factor that raises this probability," and provides a framework for risk assessment consisting of "a systematic approach to estimating the burden of disease and injury due to different risks." This approach is based on the "Red Book" framework of risk analysis developed by the American National Research Council (described in Chapter 1), and seeks to guide countries and the organization itself in assessing risk in order to take effective countermeasures and improve health.

WHO's risk assessment framework consists of four major steps. (26 p. 10) The first step is hazard identification (i.e., virus X causes disease Y). Second is an exposure assessment to estimate the extent to which a given population is exposed to the hazard. Third is a dose-response (or cause-effect) assessment that relates the probability of a health effect to the degree of exposure. Fourth is a risk characterization that consists of calculating the estimated health risk, such as the number of people predicted to experience a particular disease for a particular population. This step also includes the estimation and the communication of uncertainties. This risk assessment framework was applied in the case of the SARS outbreak.

For outbreaks of infectious diseases, this framework is used in conjunction with the *Guiding Principles for International Outbreak Alert and Response* (42) published by the Epidemic Alert and Response,[4] which is the method used by WHO to identify and evaluate health events. This method will be integrated into the revised IHR 2005 and formalized in the *WHO Event Management for International Public Health Security.* (24 pp. 8–13) It is based on surveillance, detection, verification, and risk assessment of the event to determine whether it does indeed represent an international public health risk. A notification instrument about events that may cause public health emergencies of international concern that will be included in the revised IHR as Annex 2 was available for use for the SARS case. This annex is a roadmap for assessing the seriousness, unexpectedness, and potential for international spread and for trade and travel restrictions related to a disease or an event that could be a public health emergency of international concern, and is included as Appendix 1. How the disease is spreading internationally; whether it is a known or an unknown disease; its incidence, morbidity, and mortality; the vulnerability assessment of populations, infrastructures and healthcare capacities – all of these factors inform initial decisions about how to handle the event. Since WHO considers risk assessment to be an iterative process, the method suggests continuous investigations to increase the level of information, which is of particular importance when new diseases emerge such as SARS. (24 p. 10) At the time of the SARS outbreak, there was no risk assessment method specific to the disease, the nature of which was then almost completely unknown. In 2004, WHO published a SARS-specific method of risk assessment (43 p. 31) to be used as a protocol in case SARS should resurge.

The Influenza Pandemic Plan 1999 (44) also provided some guidance for WHO's actions. Since SARS was at first mistakenly associated with A (H5N1) influenza and only later confirmed to be a new disease, the initial response included activating the influenza surveillance network. Although it may not have been directly applied once influenza was finally ruled out, the methodology of the influenza pandemic plan may have influenced WHO staff who were working on the SARS outbreak, for these personnel had also been involved in the influenza program.[5] The 1999 influenza preparedness plan included guidelines for tracking the risk and its possible sources, as well as for determining the causal chain of a pandemic risk; these guidelines were also followed in the SARS case. As prescribed by the influenza plan, WHO coordinated laboratory research to determine the characteristics of the new virus and of the SARS disease, enhanced surveillance, and developed a case definition. WHO also provided guidelines to national health authorities regarding the surveillance, risk groups, and case management, including guidance on the best available drugs. In addition, WHO set up a SARS task force as prescribed for preparedness level 3 of the influenza plan, which coordinated the SARS risk assessment process and response.

2.1.1.2 Legitimate basis for action

Two major instruments would provide the basis for the legitimacy of WHO's management of the SARS crisis: the 1969 IHR and the resolutions of the World Health Assembly of May 2003. While the resolutions adopted by the World Health Assembly for the most part validated WHO's actions, which largely relied on provisions contained in the revision project of IHR, IHR 1969 did not apply to SARS.

International Health Regulations. The SARS case raises an important issue. In 2003, the IHR of 1969 (revised in 1981), which were the only legally binding international instrument for managing infectious diseases with the potential to spread internationally, did not apply to SARS. In fact, these rules prescribed the implementation of mostly sea and air transportation measures to prevent the international spread of only three communicable diseases: cholera, plague, and yellow fever.

In 2003, IHR was under revision to produce a more adequate instrument for responding to the challenges posed by infectious diseases in a globalized world, and thus could not yet provide a legally validated basis for action. An early draft of the revised IHR was only a working document that was not yet published.[6] Nevertheless, its major provisions were summarized in the International Health Regulations Revisions Project published by WHO in 2002, and would inform WHO's response to the SARS outbreak.[7] On the one hand, WHO's actions during the SARS crisis went beyond the IHR revision project; on the other hand, the practice developed during the SARS outbreak anticipated rules that would be included in the revised IHR as finally approved in 2005. For instance, the scope of diseases would be extended to include public health emergencies of international concern. But authority to respond to emergencies of international relevance that could lead to the issuance of WHO recommendations under the International Health Regulations Revision Project of 2002 (45) (and that were applied in the SARS outbreak) was amended in the final version of the revised IHR 2005 to require consultation with state parties before the issuance of WHO's communications. This consultation was perceived as one way to better preserve the sovereignty of states in the process, although it does not preclude WHO from issuing recommendations without the state's consent.

Thus, IHR, the legally binding instrument, did not support and justify WHO's actions during the crisis, actions that complied mostly with a non-legally binding draft of rules. However, WHO's actions can be regarded as generally accepted practice, since member states effectively applied its recommendations and guidelines. Moreover, states generally complied with the obligation to report daily cases (as even China did, albeit in a later stage of the outbreak management) and with travel-related measures. Although some states, such as Canada, openly complained about the economic impact of the travel restrictions, they nevertheless complied with reporting requirements and did not engage in legal action against WHO.

In addition, the May 27, 2003, World Health Assembly Resolution on SARS and the IHR resolution, which were approved by member states, converted WHO's practices in SARS risk assessment and case management into formal rules. For example, the SARS resolution urged state members to apply WHO-recommended guidelines on surveillance, case definitions, case management, and international travel; to report cases promptly and transparently and provide other requested information to WHO; to enhance and strengthen cooperation with WHO; to request WHO support and assistance for the control measures; and to exchange information within the networks. The IHR resolution also authorized WHO to employ unofficial sources as a starting point in its outbreak verification process. A posteriori, member states approved WHO's actions and confirmed an action-based legitimacy that it gained through its management of the SARS outbreak.

The IHR revision enlisted the efforts of all 192 member states of WHO over several years, was approved by the World Health Assembly on May 23, 2005, and went into effect on June 15, 2007. The SARS story speeded completion of a revision begun in 1996. The revised IHR seeks effective surveillance of and protection from cross-border transmission of diseases, in the hope of avoiding unnecessary disruption of trade and travel. (45 p. 1) Its explicit goals are "to prevent, protect against, control and provide a public health response to the international spread of disease in ways that are commensurate with and restricted to public health risks, and which avoid unnecessary interference with international traffic and trade." (46 p. 15, Article 2) It enlarges the scope of diseases covered under the regulations, reduces dependence on country notification, improves mechanisms for collaboration, and provides incentives to encourage compliance by member states and the development of risk-specific measures to prevent the international spread of disease.

Another purpose of the revised IHR is to provide WHO with a more adaptive tool for internationally disseminating information, one based on a cooperative rather than a coercive approach as member states facing outbreaks of infectious diseases. Under the 2005 revised IHR, SARS is on the list of diseases – along with smallpox, poliomyelitis, and new subtypes of human influenza – the occurrence of which must trigger notification of WHO. However, a preliminary version of Annex 2 of the 2005 revised IHR was circulating in 2003, and SARS met the criteria of a public health emergency of international concern. These criteria consider the seriousness of the disease (in terms of morbidity and mortality), its unexpectedness, its potential to spread internationally, and the risk of restrictions on international travel and trade.

If member states fail to spontaneously report public health emergencies of international concern under IHR 2005, it would then be incumbent upon WHO to investigate rumors to determine whether there is or is not an outbreak, how serious it is, whether the disease can easily spread internationally, and whether it might require restrictions on international travel and trade. Based on this assessment of the situation, the organization determines what measures are appropriate to contain the outbreak. WHO then sets up a special task force and communication networks (including phone and email networks) to ensure that it is being constantly updated about the evolution of the disease, and conducts missions to evaluate the situation in the field. Based on the results of these assessments, WHO issues recommendations.

This is the procedure that was applied in the SARS case. After the first GPHIN and GOARN alerts, WHO requested more information from China and, based on initial reports, suspected an influenza outbreak. (47 p. 93) The investigations continued after the alert of February 11, 2003, when WHO received reports of a severe respiratory disease. Unofficial sources were the starting point for WHO's process of verifying the emergence of this new disease. Authorization for such an information investigation was not part of the IHR 1969, but would be folded into IHR 2005. The recommendations issued, as well as the surveillance system put in place, also anticipated IHR 2005. The 2002 project was thus modified by actual practice during the SARS crisis to result in IHR 2005, which was now the legally binding instrument for addressing public health emergencies of international concern.

IHR 2005 resulted from a consensus reached among WHO member states, which suggests that some requirements included in the draft revision of 2002 were softened (or even abandoned) in order to reach that consensus. The most important difference pertained to once legally binding measures that were now only recommendations. The list of diseases requiring that WHO be notified was not suppressed but extended to other diseases, and the list was complemented by the concept of a state's notifying WHO of any public health emergency of international concern. More consultation with a concerned state is generally required before the recommendations can be issued.

Most provisions included in the revision project of 2002 were put into practice during the SARS case, but there was an important difference in the decision-making process. This project did not prescribe any procedure, but during the SARS crisis, the highest level of the organization was involved in the decisions on assessing and controlling the SARS outbreak. For example, it was the WHO Director-General, Dr. Gro Harlem Brundtland, who finally decided to issue a global alert on March 15, 2003. In addition, a WHO task force was created and experts were consulted before WHO made major decisions. This practice contributed to the creation of an Emergency Committee, selected from a roster of experts, in the revised IHR 2005.

The IHR revision project of 2002 largely served as the basis for action and cooperation regarding the measures to be taken in the case of an international public health emergency like SARS. Although this document lacked formal legal legitimacy, the measures that WHO promulgated during the SARS crisis were inspired for the most part by the revised IHR draft, and were largely followed and applied by governments, organizations, and individuals. Moreover, some of these measures were validated at the time of the crisis by the World Health Assembly, which, both a posteriori and prospectively, recognized the authority and competence of WHO to use unofficial sources, to issue case management and travel recommendations, and to coordinate field actions among member states.

Resolutions of the 56th World Health Assembly in May 2003. The Fifty-sixth World Health Assembly (WHA) took place during the SARS crisis in May 2003, and adopted two important resolutions that justified WHO's role in handling the SARS outbreak and that consolidated its role as global coordinator in assessing and managing public health emergencies: the Severe Acute Respiratory Syndrome (SARS) resolution[8] and the Resolution on the Revision of the International Health Regulations.[9]

The SARS resolution. The SARS resolution constituted a formal recognition by the member states of WHO's actions during the SARS outbreak. It provided a formal and legal basis, prior to completion of the IHR revision, for further action by WHO should a SARS outbreak recur. Through the SARS resolution, member states committed themselves to intensified cooperation with the organization and among states and partners with respect to assessing the risk and undertaking the appropriate responses; making themselves extensively available if charged with operational responsibilities; providing timely, transparent, and complete reporting (for example, of the occurrence of an outbreak and the number of cases); and reinforcing surveillance systems.

At the time of the SARS outbreak, WHO lacked a mandate to act as an international health police that could force countries to report. (48) This resolution not only confirmed the practices WHO followed during the SARS crisis but also represented a commitment by the states to comply with its requirements. Until the revised IHR could be finalized, it would help prevent certain uncooperative state behavior that could jeopardize the global response. Certain affected member states, like Vietnam, Singapore and Hong Kong provided daily reports of the number of cases, replied promptly to requests for information, and cooperated in the management of the crisis since its beginning. China began to fully cooperate on April 1, 2003, and after some episodes of incomplete reporting, Canada also began to fully comply. During the SARS crisis, international cooperation reached an unprecedented level with the deployment of field teams (upon the request of countries such as Vietnam and Taiwan) and the coordination of scientific efforts around the world. WHO wished somehow to institutionalize this cooperation in preparation for responses to future crises. Passage of the resolution showed that, for the most part, states supported its actions in the SARS crisis, which reinforced the role of the organization.

Finally, the SARS resolution strengthened WHO's risk assessment and risk management mechanisms. It requested the strengthening of the Global Alert and Response Network and the collaborative networks, further development of research and country assistance programs, and the application of lessons learned from the SARS experience to revisions of the International Health Regulations. After the outbreak was declared over in July 2003, WHO carried out initiatives to build on the knowledge it had acquired and to increase preparedness levels should SARS resurge. As IHR was revised, standardized guidelines in aviation were also updated. Aid and loan reallocations were provided to improve the surveillance and response capacity of some national health infrastructures – for example, that of Vietnam.

The resolution on the revision of IHR. The resolution on the revision of IHR acknowledged the inadequacy of the current (1969) IHR to cope with the emergence and rapid international spread of SARS, and it treated the revision of IHR as a top priority. It first established "an intergovernmental working group open to all Member States to review and recommend a draft revision of the International Health Regulations for consideration by the Health Assembly under Article 21 of the WHO Constitution." Within this new structure, WHO was in charge of completing the technical work of IHR, keeping member states informed about the work in progress, and facilitating the reaching of an agreement. Participants from other organizations and observers could be invited to attend the work sessions of the intergovernmental group in which the participation of developing countries was to be facilitated. The establishment of focal points[10] on the basis of the SARS resolution for public health emergencies in general was also determined, as were the terms of enhanced cooperation with veterinary, agricultural, and other relevant agencies involved in planning and implementing preventive and control measures. For example, joint research with other agencies was carried out with regard to animal reservoirs of SARS and risks of resurgence of the disease. This acceleration of the revision of IHR resulted in its voluntary early adoption in 2005. It came into effect on June 15, 2007.

In addition, WHO became a more independent and rapid risk assessor, since a state's notification of an outbreak was no longer the single recognized channel of information. One major provision of the resolution, which would also be included in the revised IHR of 2005, was the possibility for WHO "to take into account reports from sources other than official notifications, to validate these reports according to established epidemiological principles." (48) This resolution confirmed WHO's practice in the case of SARS, when the organization verified the rumor picked up by GPHIN. Ultimately, the revised 2005 IHR will oblige states to respond in a timely manner to WHO's requests for verification in the case of a suspected public health emergency of international concern; this was not the case with respect to the Chinese government, which withheld information at the beginning of the outbreak, controlled the media, and refused international access to SARS victims (48).

The resolution on the revision of IHR also recognized WHO's right to alert the international community after having informed the government most directly concerned. In the revised IHR 2005, this provision requires consultation with the affected state party before WHO can issue an alert. This modification indicates that states wish to retain a certain degree of control over the organization's decisions by being able to express any concerns about the impact of the alert before it is issued.

Finally, this resolution formalized the collaboration of WHO with willing state members to assess the severity of the threat and the adequacy of control measures, and it proposed "on-the-spot studies" by WHO teams to evaluate the implementation of control measures. During the course of the SARS crisis, WHO was finally able to send field missions to China, but the late and reluctant consent of Chinese authorities delayed the risk assessment. Vietnam, by contrast, requested such intervention immediately. Under the resolution and the revised IHR 2005, WHO can still intervene, but, as before, only upon being invited to do so by the member state.

WHO practices during the SARS crisis, largely inspired by the 2002 IHR revision project, led to official recognition and acceptance of those practices by member states in the form of the adoption of two resolutions in late May 2003. Nevertheless, at the time the global alerts and travel recommendations were issued, there was no formal and documented delegation of this authority to WHO. WHO's actions preceded the enactment of formal authorizing rules, but this usually takes place the other way around.

2.1.2 Mobilization of expertise

The multidisciplinary composition and international track record of the experts involved in the SARS risk assessment process and the integration into the risk assessment of the latest research results available in the course of the outbreak characterized the expertise that WHO mobilized to address the risk of a pandemic. SARS expertise consisted of a WHO SARS task force composed of officers and staff from headquarters, the Western Pacific Region Office in Manila, country offices, and external experts.

The WHO SARS task force, led by Dr. David Heymann, managed the outbreak in close collaboration with the WHO Western Pacific Regional Office in Manila. SARS-dedicated teams made use of operations rooms with all modern means of communication, both at headquarters and at the WHO Western Pacific Regional Office in Manila. At WHO headquarters, a team of about 30 to 40 people worked on the SARS outbreak, forming an intelligence network group and a risk assessment group staffed by experts on international health regulations and specialists on diseases such as influenza or cholera.[11]

On March 7, 2003, the WHO Western Pacific Regional Office formed an ad hoc team to deal with outbreaks that might be public health emergencies of international concern and to establish a Surveillance and Response Unit responsible for coordinating two teams: the SARS Response Group to support teams in the field in affected countries, (34 p. 61) and a SARS Preparedness Group to operate in vulnerable countries in order minimize the risks of importation of the disease to other countries.

This task force at headquarters and regional offices played a key role in both risk analysis and response coordination and implementation. In affected areas, the key activities of the SARS Response Group focused on hospital and infection control; surveillance; quarantine; laboratory testing; human resources, logistics, and supplies; and public information. (34 p. 61) The SARS Preparedness Group, for its part, sent public health and infection control experts to vulnerable countries to strengthen surveillance and develop contingency plans. Field support was provided for countries suffering from local transmission, including Hong Kong, China, Singapore, Vietnam, and the Philippines. In the meantime, experts were sent to vulnerable countries like Malaysia and Laos to help them prepare for a SARS outbreak.

In 2003, WHO requested support from the GOARN overarching network that linked in real time 115 experts from 26 institutions in 17 countries. (49 p. 185) These institutions have the capacity and resources to detach specialized and experienced personnel to provide data and perform laboratory tests. GOARN's broad geographical base enabled it to send field teams to five countries. However, the WHO regional office in Manila also organized teams of experts and consultants, since GOARN could not respond to every need and WHO had a stronger presence in America and Europe. The WHO regional office in Manila requested support from other networks as well, including the Training in Epidemiology and Public Health Interventions Program Network (TEPHINET), Field Epidemiology Training Programs (FETPs), and various academic institutions (34 p. 62).

WHO also hired consultants to act in the name of the organization in field missions, and who were often assimilated into WHO personnel. The three virtual collaborative networks created to work on the SARS outbreak gathered external experts in their respective fields (see further details on virology, clinical aspects, and epidemiology networks). WHO also mobilized and integrated local expertise in the hospitals, universities, and state agencies of affected countries.

2.1.2.1 Background diversity

When examining the SARS outbreak, a key requirement is attentiveness to broad-based expertise – scientific, technical, geographic, and institutional. Such expertise is manifested in teams, field missions, scientific networks, and technical meetings.

Multidisciplinary teams The two poles of expertise – internal WHO expertise and external expertise – were combined for interventions in the field. These teams were composed of persons with expertise that ranged from clinical management, communication, epidemiology, and public health to infection control, laboratory work, logistics, psychology, and animal health. They came from many different organizations based in many different countries, and included WHO headquarters, regional offices and country offices, NGOs such as Médecins sans Frontières (MSF; Doctors Without Borders), hospitals, laboratories, universities and research institutes, ministries of health and health agencies, centers for disease control, animal research institutions, independent experts, and private companies.

To deal with the SARS outbreak, 16 institutions of the GOARN network from 12 countries offered the assistance of clinicians, data managers, infectious disease experts, epidemiologists, laboratory experts, logistics experts, medical epidemiologists, microbiologists, media experts, pathologists, public health specialists, and virologists.[12] The GOARN teams that worked on the SARS epidemic were composed of 60 experts representing 20 organizations and 15 nationalities. They collaborated with national authorities on case management, infection control, surveillance, and laboratory and epidemiological investigations in China, Vietnam, Singapore, and Hong Kong. (51) Field missions also included experts from both WHO and other organizations.

WHO has published a list of about 300 technical staff and consultants (including GOARN experts) who provided support during the SARS pandemic for the region's response.[13] The list classifies people by type of intervention, country of intervention, field of expertise or area of work, organization, country base of this organization, and duration of their intervention. Table 2.1 shows the proportions of the professional backgrounds of those experts who worked with WHO between March 12, 2003 and July 16, 2003 (52).

Most of the experts came from the field of epidemiology and public health (32%), infection control (15%), and laboratories (6%). Data are missing about the fields of expertise of the WHO headquarters' staff (19%) involved in dealing with the SARS outbreak, and also the WHO and USA CDC personnel involved in field missions (9%). But the data show that the 22 American CDC staff members were exclusively involved in the Taiwan mission. The analysis is more precise when the field missions specifically are considered.

About 244 (53 p. 1731) of these 327[14] technical staff and consultants were assigned to field missions. Epidemiologists represented 43% of

Table 2.1 SARS technical staff and consultants by area of work and field of expertise

Area of work / field of expertise	Number of experts	Experts in %
Epidemiology and public health	106	32.4%
WHO Headquarters	61	18.7%
Infection control	49	15.0%
Unspecified USA CDC / WHO	29	8.9%
WHO other regional and country offices	22	6.7%
Laboratory	19	5.8%
Communication	15	4.6%
WHO country office	12	3.7%
Logistics	6	1.8%
Clinical management	2	0.6%
Animal health	2	0.6%
Psychology	1	0.3%
Administration	1	0.3%
Funding	1	0.3%
Other	1	0.3%
Total of experts involved in SARS outbreaks (Feb.–July 2003)	**327**	**100%**

the staff, infection control specialists 20%, laboratory experts 8%, and communication 6%. Experts in logistics, clinical management, animal health, psychology, administration, and funding remained in the same proportion as shown in the table above. Teams were multidisciplinary and combined expertise from different areas. A psychologist and a communication specialist might collaborate to ensure that messages about protection measures were effectively promulgated among the populations affected and the medical community. Thus, missions were rarely composed entirely of technical experts but also included social, psychological, and communication experts.

The field missions in Vietnam, Hong Kong, and China integrated multiple fields of expertise and a range of institutions from different countries. The team that intervened in Vietnam was composed of about 30 experts who were active in five different fields and associated with ten different organizations located in eight countries.[15] The team sent to Hong Kong was composed of 23 experts who were active in four different fields and associated with 12 institutions located in seven countries. The largest mission in China was composed of 77 experts from 27 institutions and 16 countries, who were active in seven fields.

All three missions included a majority of epidemiologists in order to better track and understand the behavior of the disease, as well as a significant proportion of infection control specialists to evaluate the situation and the implementation of control measures. However, the composition of the teams and therefore of the fields of expertise varied from one mission to the next, depending on the local needs and capacities in affected areas. Laboratory experts were sent to China to cope with the lack of resources in certain areas, for example. Both Hong Kong and Singapore received smaller teams with fewer fields of expertise, since more specialists were available locally and authorities had more resources and ability to deal with the outbreak than was true in other affected countries. The participation of psychological and communication experts showed that not only technical aspects of the disease but also behavioral aspects relevant to communication about measures to combat the crisis and explanations about risk were also crucial to the success of the intervention. The participation of NGOs such as MSF in Vietnam also permitted more precise evaluation of the situation and better dissemination of the measures to be applied. Animal health expertise was concentrated in China, where investigators sought to learn whether the virus had an animal origin.

Thirteen missions were conducted in affected areas, including the preparedness missions carried out in vulnerable areas. Although the teams were diverse, resources were not abundant enough to allow all relevant fields of expertise to be systematically represented in each mission. In particular, expertise was underrepresented in the field of social sciences. While economic and funding aspects were taken into account from a macro-perspective, field missions did not systematically address financial considerations nor enlist economists to assess the impact of the disease and countermeasures on local economies. Similarly, no legal experts participated in critical missions to ensure respect for local laws by the field teams, as well as compliance with international regulations in the fields of health and trade. Neither sociologists nor anthropologists, who could provide input on risk perception and cultural approaches to health risks, were involved in field missions. Finally, although logistical planning was carried out essentially from the WHO Western Pacific Regional Office, logistics specialists were not systematically involved in supporting field missions.

International track record. Both experts from WHO and external experts in charge of risk assessment had an international track record in their area of expertise, including publications in prestigious journals like *The Lancet* or *The New England Journal of Medicine* or referenced in MedLine. Most could point to practical experience in the field in managing infectious disease outbreaks.

WHO set up a SARS task force of highly qualified and internationally recognized professionals to lead the risk assessment and the response to SARS. This task force benefited from the solid track record of three key individuals who played an important role in dealing with the outbreak and in recommending action to the Director-General: Dr. David L. Heymann, Executive Director of the WHO Communicable Diseases Cluster; Dr. Michael J. Ryan, Coordinator of WHO's Global Alert and Response program; and Dr. Klaus Stöhr, Coordinator of the World Health Organization's Global Influenza Program. They had published over 200 scientific articles on infectious diseases and related issues in peer-reviewed medical and scientific journals, and authored several chapters on infectious diseases in medical textbooks.

Another example is the first global conference on SARS epidemiology that was held at the WHO headquarters in Geneva from May 16 to 17, 2003. About 100 participants from 16 countries gathered face to face and via video and audio linkups to share their experience. They represented academic institutions, health agencies, centers for disease control, representatives from all regions experiencing SARS outbreaks, and WHO itself (about 40 persons). Leading international experts in the fields of communicable disease epidemiology, mathematical modeling of public health, and clinical virology attended the meeting. The work of the epidemiology network was documented in the *WHO Consensus Document on the Epidemiology of SARS*, (53 p. 1731, 54 p. 115) which summarized the current understanding of SARS epidemiology, identified gaps in knowledge in order to launch further epidemiological studies, and determined how the SARS epidemiology network could support these initiatives. This meeting fostered discussion about and dissemination of the latest knowledge about SARS by scientists who were members of renowned organizations around the world, even as the SARS outbreak was getting under control.

Some indication of the international track record of the participants is shown by the fact that over a ten-year period ending in 2003–2004, *The Lancet* published 98 articles by the participants and *The New England Journal of Medicine* published 21 by them.[16] The eminent specialists in epidemiology who gathered at the Geneva meeting represented the whole range of expertise involved in the risk assessment of SARS.

2.1.2.2 Integration of latest research results

The quality and transparency of research is a key aspect of quality risk analysis. When the first global alert was published on March 12, 2003, almost nothing was known about the disease except that it was a contagious respiratory infection that could spread internationally and cause death rapidly. The acquisition and sharing of knowledge was essential to the design of a risk assessment that could inform an appropriate international response. During the SARS outbreak, WHO defined and coordinated the efforts in three areas of research: laboratory identification and testing of the SARS virus, epidemiology of SARS, and clinical aspects of the disease.

WHO played an instrumental role in rapidly setting up a collaborative network that included qualified personnel from institutions located across continents. Although this way of working was new, these institutions had international credentials and resources, and most had benefited from a history of collaboration with WHO. Risk assessment was updated as research about the disease progressed, whether as a result of the discovery of the new virus at the end of March, improved knowledge about the symptoms and reactions to treatments, or better understanding of the transmission routes of the virus. Secure Internet-based exchanges of information and regular video conferences were privileged forums for cooperation among these experts. Later in the course of the outbreak, WHO organized technical meetings. The first meeting of experts, held in Geneva on May 16–17, 2003, was thought to reflect the "latest and best scientific knowledge."

Virology laboratory network. On March 17, 2003, the GOARN, led by Dr. Michael J. Ryan was coordinating 11 laboratories[17] in 9 countries in an international multicenter effort to identify the causative agent of SARS. Identifying this agent would permit resort to more specific measures than merely isolation and quarantine – for example, the development of a vaccine in the case of viral origin, or the administration of more specific drugs for treatment. Dr. Klaus Stöhr, who had been running the Global Influenza Program, was in charge of creating that network. The decision to set it up was made on March 15, 2003, the day the emergency travel advice was published. The institutions were selected on the basis of their outstanding experience in detecting a wide range of viruses and other microorganisms, history of collaboration in international investigations coordinated by WHO, access to SARS samples, high-level facilities, and capacity to fulfill the six criteria of Koch's postulates[18] required to establish a virus as the cause of a disease. Over the weekend, the network was constituted on the basis of the influenza network[19] and the capacity of these laboratories to ensure virtual collaboration.

The partners in this network shared the results of their investigation of clinical samples from SARS cases (e.g., virus identification and characterization) in real time by email and on a secure website, as well as through daily teleconferences. Samples from the same patient could be analyzed simultaneously in several different centers, employing different techniques, and the results could be compared rapidly. The research rapidly progressed toward the identification of a new virus. On March 27, WHO announced on its website that scientists of this lab network had identified a new member of the coronavirus as the causative agent of SARS. Already, on March 21, the Hong Kong University team of Dr. Malik Peiris had announced its isolation of the virus and communicated it to Dr. Klaus Stöhr at the WHO headquarters. (53 p. 1731) The Hong Kong team provided evidence that a virus in the coronavirus family was the causal agent of SARS, (57 p. 1324) working with a sample of 50 patients, all ethnic Chinese, of whom 8% had recently traveled to mainland China. (57 p. 1320) They also made available their virus isolate to members of the network for further checking and confirmation, which was obtained from the Netherlands partners (58).

Dr. David Heymann, Executive Director, Communicable Diseases, publicly recognized that the Hong Kong team was the first to discover and identify the SARS virus, which was collectively announced once all tests had been performed on April 16, 2003. (53 p. 1732) While international collaboration appeared necessary to tackle the global risk of a pandemic, the initial idea of a collective publication of research findings did not come true. Competition among the institutions to publish the results first in academic reviews remained an issue, although the collaboration did lead to the identification of the causative agent in a relatively brief period of time.[20] The Hong Kong team was the first to publish its results, which appeared in *The Lancet* on April 8, 2003, garnering international recognition. (54 p. 121) The other teams published in equally renowned publications; the American CDC and a group of scientists in Germany and the Netherlands published articles in *The New England Journal of Medicine* on April 10, 2003. (54 p. 121) This race to publish showed that it was a difficult enterprise to set up these collaborative networks and make them function. Even so, the latest knowledge available about SARS was originating in this network coordinated by WHO.

The discovery of the virus was considered to be a turning point in the research, for it uncovered the cause of SARS and allowed for a more precise risk assessment and more focused recommendations. The latest available knowledge contributed to the refinement of the risk assessment due to a better apprehension of the contagious properties of this virus. This progress in knowledge about the disease, together with the observation that sick people were continuing to travel, contributed to the issuance on March 27 (the same day that the discovery of a new coronavirus was publicly announced) of a WHO travel advisory to international travelers and airlines. WHO recommended the screening of passengers departing from airports in affected areas. In addition, the viral origin of SARS opened the door for new research to develop diagnostic tests (to replace case definitions), vaccines, and drugs. These research tracks were expected to generate targeted measures for improved detection, containment, and treatment of SARS. The virology network results would have an even greater impact in the long run if they could lead to the production of a vaccine or specific drugs. Based on the network's results, WHO could envisage the development of alternatives measures of containment to isolation, quarantine and health-care staff protection, measures that were very costly and time consuming in affected areas.

Epidemiological network. On March 28, 2003, the GOARN set up an epidemiology network that included 32 epidemiologists from 11 institutions (57 p. 1324) in nine countries and that was coordinated by Dr. Mark Salter from WHO.[21]

The objective of the epidemiology network was to provide data and to share the results of its work in order to reach a consensus on the epidemiology of the disease and then, on that basis, to design the appropriate public health response. The key elements to agree upon were the incubation period, the period of communicability, the modes of transmission of the virus, and the identification of risk groups and factors. While Canada had epidemiologists, GOARN epidemiologists were dispatched to other affected areas, such as Vietnam, Singapore, and Hong Kong.

Evolution of knowledge about the epidemiology of the disease had consequences for the measures adopted by WHO. For example, the discovery that a coronavirus was the source of the disease confirmed that it was spread by droplets or by direct and indirect contact, although airborne and fecal-oral routes of transmission could not be ruled out. It was established that transmission was essentially limited to close contacts via droplets, although some routes of transmission had not been fully determined in some clusters, such as the Amoy Gardens or Metropole Hotel outbreaks. (34 p. 189) In the cluster of cases originating in the Metropole Hotel in Hong Kong, the air conditioning system could have been a vector of transmission, or, as Hong Kong Health Department director Dr. Margaret Chan speculated, (59) "perhaps they all stood outside the elevator at the same time and someone sneezed or coughed." These elements of analysis contributed to the issuance of the screening recommendation of March 27, 2003 and, what is more important, to the travel advice of April 2, 2003 recommending that unnecessary travel to Hong Kong and Guangdong be postposed.

Clinical network. On March 17, 2003, WHO set up a collaborative network of 50 clinicians (60 p. 13) in 14 countries[22] to acquire knowledge of symptoms, diagnosis, and treatment of SARS from the hospitals in the affected countries and territories. The objectives of this network were to gather, compile, compare, and archive case management data from all affected hospitals (including x-ray, laboratory, and other findings); update the case definition; prepare guidance for clinical diagnosis; and develop treatment guidance, including discharge criteria. (61) On March 26, the first "ground rounds"[23] consultation on SARS symptoms, diagnosis, and management initially gathered 80 clinicians from 13 countries in real time (62).

On a daily basis, hospitals in this network exchanged and reviewed diagnostic and treatment results, as well as case management. The results of this consultation were published immediately on the WHO website so that they could be readily accessible to WHO members, partners, and the general public. This network helped produce the latest insights into the disease, to search for an effective cure, and to improve hospital infection control measures and clinical guidelines for the management of SARS cases and their contacts. (50) During the press conference on April 11, 2003, Salter explained its benefits: "We now know from their work and bringing it together, again on a secure website, that of those who contract SARS, 96% are getting better; 4% are dying; 10% of all the numbers are requiring admission to intensive care units, of whom approximately 50% are requiring mechanical ventilation" (58).

This information was further used as the basis for a continuous risk assessment to better prepare the health-care structures to deal with these patients in affected countries. Progress in learning about the symptoms and treatments enabled a consensus about the clinical signs of SARS. This knowledge also made it possible to refine case definitions (last updated on May 1, 2003) and case management guidelines (last updated on April 24, 2003).[24] But at that time, uncertainty remained about the clinical indicators that would allow distinguishing between the 90% of people who could recover from the disease and the 10% who would require intensive therapy and die from it (58).

The results obtained from the studies on the characteristics of SARS, such as its means of transmission and control, were shared within the network of clinicians, making it possible to refine the risk evaluation and the content of the SARS disease control guidelines. The clinicians' network produced infection control guidelines and contributed to the development of case definitions (60 p. 13) that were periodically revised. Clinicians were asked to provide clinical records about chest X-rays, clinical courses, laboratory data and incubation periods, all of which was information required in order to understand the natural course of the disease and its clinical presentation. Such data, which was made available through the network, led to the development and revision of the guidelines. For example, as a result of the investigation in the Guangdong Province in the beginning of April, case definitions were updated with more precise elements developed by Chinese scientists, who had been confronted with the disease for a longer period of time than other researchers.

WHO also regarded this collaborative work as a way of fostering the development of more effective infection control measures, which had been fundamental in halting the transmission of SARS in many countries. (58) The network improved knowledge of the disease's symptoms and diagnosis, thereby making possible more adequate treatments. The results of the ground rounds, combined with the assessment of the WHO team in China that the cases were most probably SARS, and the identification, on March 27, of the causative agent of SARS, generated the second travel advisory of March 27. The new advisory went beyond that of March 15 in prescribing the screening of air passengers who were departing from a small number of affected areas for another country.

In summary, WHO and teams in the field used the latest results of researchers who were participating in the SARS-dedicated international collaborative networks focusing on virology, clinical management, and epidemiology. WHO's risk analysis thus encompassed the latest insights about SARS. This was particularly critical in the context of such an emerging disease, the combating of which involved making decisions and proposing measures despite chronically high levels of uncertainty, for which no specific standard protocol was in place and that necessitated innovative ways of addressing the risk.[25] WHO relied on the continuous and rapid acquisition of knowledge about the disease, and efficient integration of its latest state of knowledge into the recommendations that would be publicly communicated. For example, the identification of the virus enabled the refinement of case definitions and case management guidelines. Similarly, the exchange of descriptions of cases, courses, and diagnostics provided input for updating case definitions that could then be submitted to health authorities for screening.[26] WHO could not rely on preestablished strict guidelines due to the fact that the disease was hitherto unknown. The risk could not be calculated upfront due to the lack of sufficient data to quantify it with a satisfactory level of confidence. WHO followed the research closely and adapted its guidelines on the basis of each new element, motivated by a constant concern to prevent a global epidemic.

2.1.3 Risk assessment process

Planning, the mobilization of expertise, and the integration of the latest available research are essential but not sufficient conditions to complete a risk analysis. Risk assessment mechanisms have to be deployed in order to identify and evaluate the risk.

2.1.3.1 Observation system

The SARS risk assessment was based on an observation system consisting of three pillars that each contributed to better-informed decisions: rumor surveillance at the initial stages of the outbreak, the influenza surveillance network when an influenza outbreak was suspected, and SARS-specific virology, clinical, and epidemiological networks set up in the course of the outbreak.

Rumor surveillance. The rumor surveillance process relied on two major sources: the GPHIN for media sources and rumors promulgated by anonymous individuals. The GPHIN raised the first alert about the SARS outbreak, as it did for other outbreaks between 1998 and 2001.[27] The GPHIN is an early warning system that scans rumors and reports of suspicious diseases (34 p. 51) that are the basis of a daily risk assessment performed at WHO headquarters in Geneva. The interest of such a system in the case of a new disease outbreak such as SARS was to report unofficial information about unusual events relevant to public health that governments might be reluctant to report and to speed up the exchange of information to promote early international action to contain a possible epidemic. However, the system was overwhelmed during the SARS outbreak, encountering access problems. In addition, the GPHIN was limited to French and English news. Its efficiency in developing countries, where little information is posted on the Internet, and information is often subject to government censorship (64 e14) has been questioned. Since the SARS outbreak, this system has been further developed in order to upgrade its platform and cover more sources in several additional languages.

The second source of rumors was individuals. A first email sent on February 10, 2003, to Alan Schnur, Communicable Disease Team Leader of WHO China, by the son of a former WHO staff member reported a "strange contagious disease" that "left already 100 people dead…in Guangdong Province, in the space of one week." (34 p. 75) The email was followed by anonymous emails of members of the public or NGOs reporting to WHO that people who had contracted an infectious disease had been admitted to different hospitals in various regions. WHO then contacted governments to obtain up-to-date and accurate information about the outbreaks. Two-thirds of the rumors were confirmed (34 p. 70).

These two major unofficial sources supported WHO in its SARS risk assessment by providing information on the local and international spread of the disease. The system of rumor surveillance also provided WHO with more accurate and updated information when countries delayed in reporting SARS cases to minimize the economic consequences. In terms of the verification process, it appears that WHO remained dependent on the response of national governments to its information requests to allow field evaluation missions in the affected regions. The verification process of the first rumor was impaired by information biases and by organizational and structural factors. (65) First, an atypical pneumonia is not rare in the Guangdong Province in China. Second, rumors were not unusual in China, but often appeared to be false. Third, a bias occurred in the analysis, since the Guangdong Province is associated with a risk for avian influenza. Fourth, the delay in Chinese responses after numerous tentative efforts to obtain information (information requests initiated by the WHO report of Dr. Alan Schnur to Dr. Hitoshi Oshitani, WHO's Regional Adviser for Communicable Disease Surveillance and Response, and then to WHO headquarters, which sent an official letter from WHO to the Chinese Ministry of Health, which did not immediately reply). Fifth, incorrect identification of chlamydia as the source of the disease by the Chinese scientists – and cultural pressure to stick to that response even when scientists in Beijing identified a new virus late February 2003 – revealed structural deficiencies in the scientific analysis of health issues in China.

The rumors surveillance system captured initial information that was analyzed by WHO and verified with authorities of the states concerned. In the case of SARS, this information about rumors initially fed the risk assessment process, and China's attitude, along with the rapid international spread of the disease, increased the risk for the organization. The process of verifying the rumor was key as it was the first analysis that determined the presence – or absence – of a potential risk, and the necessity of launching the disease identification process. This identification process was biased by the false intuition about possible avian influenza cases, which probably delayed investigation of other possible sources of the disease. In addition, the reluctance of the Chinese authorities to provide critical information (such as the identification of a new virus at the end of February) and to allow teams of experts to visit the Guangdong Province prevented the possibility of identifying the cause of the disease sooner. It was only after the disease had spread to Hong Kong and Vietnam that analyses became easier and similarities could be found and eventually traced back to Guangdong Province.

Global Influenza Surveillance Network. The GOARN placed the WHO Global Influenza Surveillance Network under alert in late November 2002, following the GPHIN report of an influenza outbreak in mainland China. (47 p. 93) This was the first time in the SARS outbreak that the influenza surveillance network was solicited. Influenza surveillance, which had been established in 1947, is the oldest disease control program at WHO, and is one major partner in the GOARN. (47 p. 93) This network of laboratories was set up to gain a global view of influenza viruses and their implications for human health. These laboratories freely share influenza viruses collected from around the world and related documented analysis among themselves and with vaccine manufacturers. In 2003, the network consisted of 112 national influenza centers in 83 countries and the four WHO collaborative centers for reference and research on Influenza.[28]

The national centers collect influenza viruses and send them to the four collaborating laboratories for investigation and analysis. These four centers are able to compare virus samples to historical data that they have stored and to provide diagnostic support for the countries experiencing unusual influenza cases, such as the ones caused by the H5N1 virus. These comparisons are useful for confirming the type of virus and determining its evolution and possible instances of human-to-human transmission.

As a result of the first alert, the laboratories of the WHO global influenza surveillance program verified the December 12, 2002, report of Chinese surveillance sites in Beijing and Guangdong. This verification confirmed Chinese reports of cases of influenza B. In fact, as would become known only after WHO's team of experts visited Guangdong Province to review the outbreak of atypical pneumonia in the province, there had been two disease outbreaks: an outbreak of influenza from an avian origin, and an outbreak of what would become known as SARS.

The SARS outbreak intensified, giving rise to the second rumor of February 10, 2003, and generating the second alert of the WHO Global

Influenza Network. Since the outbreak concurred with the detection of the A (H5N1) virus in two persons in Hong Kong, it also resulted in the activation of the WHO Pandemic Preparedness plan. The laboratories analyzed the specimens of a patient in Hanoi, while the GOARN teams in Vietnam and Hong Kong collected information about this patient and a growing number of others with similar symptoms. (53 p. 1730) The work of the Global Influenza Network activated on February 19, 2003, enabled the gathering of enough clinical and epidemiological information to warrant the issuing of the first global alert about a new infectious respiratory disease on March 12, 2003. The network also ruled out all influenza virus strains and other known causes of pneumonia from the samples taken in Hanoi, Singapore, and Hong Kong, thereby bolstering the assessment that SARS was a new disease. After this first alert, and concurring with the emergency travel advisory of March 15, 2003, this network was supplemented by the establishment of three SARS-dedicated epidemiological, clinical, and virological networks that were instrumental in the risk assessment.

SARS dedicated networks. The SARS dedicated networks also served as surveillance networks, knowledge sharing forums, and research production networks.

The SARS virology laboratory network was closely linked to the already existing WHO influenza network. It included WHO national influenza centers and WHO collaborating centers, which reinforced continuity of collaboration and developed synergies with the regular influenza surveillance program. This closeness arises from the fact that both diseases are infectious, with comparable characteristics and that the influenza network had already been alerted in response to the suspicion of an avian influenza. This virology laboratory network was in fact composed of thirteen institutions, of which eight[29] were national influenza centers (NICs) and three were WHO collaborating centers (CCs) and NICs simultaneously.[30] This network, which was initially modeled on the influenza surveillance network, evolved into a specifically designed SARS network according to the characteristics of the disease.

This surveillance network was essentially based on preexisting cooperative structures of WHO in the field of influenza, which were used to unravel the nature of the new disease in order to protect populations from it. The network worked and communicated its results about the causative agent of the virus and its characteristics, which, in turn, enabled the refinement of the risk assessment and the design of more precise recommendations and guidelines. These clinical and epidemiological networks were also set up to enhance the surveillance of the disease and its evolution. The mission of these centers was to discover what caused the disease, how it spread, and how it could be treated (54 p. 93).

The observation system deployed for the SARS disease acted on both national and international levels. National health authorities gathered information from their national surveillance systems (some of them, through partners of WHO's influenza surveillance program) about a new emerging infectious disease, information that they transmitted to WHO. At the international level, the GPHIN raised the alert, and the WHO influenza surveillance system and, later, the SARS dedicated networks were used to watch closely the development and spread of the disease. Information communicated by national authorities, combined with the information from experts involved in the virtual networks and in the field, was key to advancing knowledge of the disease and to refining the risk assessment in order to issue further travel recommendations and case definition and management guidelines.

The existence and effectiveness of surveillance systems in developing countries was often mentioned as needing improvement. In China, laboratories that joined the surveillance system of WHO shortly before the outbreak of SARS had difficulty being effective and communicating clearly due to the country's policy of secrecy. In China, investment was made in an electronic reporting system based on the national existing surveillance system during the SARS crisis in order to produce more accurate and updated reports of cases on a daily basis. (66) Vietnam requested assistance, and it promptly and spontaneously reported SARS cases to WHO. Hong Kong and Singapore installed detection and reporting of cases as soon as the outbreaks started, and voluntarily reported their cases to WHO as well. Usually, WHO case definitions were used as the basis for both national and international reporting.

Although the observation system was imperfect at the WHO level and at national levels, it contributed to the risk assessment of SARS by providing information about the start of the outbreak and its evolution. First, the identification of a new emerging disease was accomplished, thanks to concurring information from two WHO-related observation systems. Second, the evolution of the disease was closely watched, thanks to national surveillance systems of countries that reported their information to WHO so that it could update the global surveillance system (e.g., Vietnam, Singapore, Hong Kong). Finally, the SARS dedicated networks provided one common channel of information for discussing and assessing the global risk of SARS and proposed SARS disease management solutions. WHO in cooperation with national health authorities (except for those of China, at the beginning of the outbreak) was able to centralize relevant information about the disease in order to establish possible connections between the outbreaks in different countries (China, Hong Kong, and Vietnam). It was able to estimate on the basis of reported symptoms that the infection could be the same disease, and that this disease presented the capacity to spread via international air travel.

2.1.3.2 Risk assessment mechanisms

The risk assessment mechanisms applied by WHO included the application of its general risk assessment method, the decision instrument for the assessment and notification of events that might constitute a public health emergency of international concern – the future Annex 2 of the revised IHR – and the *Guiding Principles for International Outbreak Alert* (42) to identify the risk source and estimate the risk and the seriousness of its consequences. WHO used a combination of new mechanisms such as the networks of experts and the ground rounds, supported by modern technological tools like web-based technologies and videoconferences, with older mechanisms like contact tracing also supported by such new technologies as electronic mapping. The risk assessment mechanisms resulted in an estimation of the risk that was not expressed as a probability, but rather as a scenario that took into account the disease characteristics, the virus characteristics once they became known, and the level of uncertainty. In this analysis, actions to protect populations and reduce uncertainty played a key role. The absence of knowledge at the initial stage was addressed by early decisions on standard precautionary measures such as isolation of patients and quarantine until the disease and its modes of transmission could be better known, which were expected in turn to help evaluate and potentially reduce the global impact of the disease. Subsequent discoveries allowed for more targeted measures to reduce the risk.

Application of risk assessment method. The *Guiding Principles for International Outbreak Alert* sets forth more specific guidelines that are compliant with the general risk assessment framework and that specifically apply to outbreaks of infectious diseases. They include detection, verification, and communication of the outbreak, as well as risk assessment steps. In this risk assessment, WHO considers elements such as context, the fact that the disease is unknown, its rapid international spread, its serious health impact (contagious disease causing death), its transmission capacity, it potential impact on travel and trade, and the capacities of infrastructures and health care to handle the disease and make initial decisions on how the event should be handled.

Detection usually functions based on the Outbreak Verification List, a daily list containing reports on rumors of outbreaks that have ben identified by national or regional offices, national governments, and media. After WHO verifies that there is a public health event, this list is made available on a confidential basis to public health professionals around the world. (67 p. xv) Once the outbreak is confirmed by the country, WHO publicly announces the presence of the outbreak. In the case of SARS, on February 10, 2003, WHO received a report about 300 cases, of which five were deaths from an atypical pneumonia in the Guangdong Province that the Chinese authorities, in a press conference, said was under control. The context of the spread of a new contagious and deadly disease, China's refusal to cooperate, and the situations reported in Vietnam and Hong Kong made the presence of an outbreak in China likely. But information was still missing.

WHO used other information sources (media, NGOs, other United Nations agencies, and partners in its GOARN to identify areas in which there might be new cases. Once cases were suspected, WHO and its partners followed up with countries to establish whether cases were actually occurring and what measures were being implemented to ensure containment. An epidemiological team systematically analyzed data and conducted risk assessment. (50) This analysis also entailed contact tracing to identify index cases and possibly all secondary cases in order to learn more about the transmission of the disease, and, in the end, about its origin.

Hazard identification included identification of the risk source or causative agent and the assessment of the cause-effect relationship. At first, very little epidemiological information was available. A severe respiratory disease could cause death quickly, and occurrences of nosocomial transmission and household transmission seemed to imply that prolonged contact was necessary to transmit the disease. Risk tracking, including laboratory research and testing, was performed in order to identify possible sources for the disease and points of origin. When Hong Kong reported two human cases of avian influenza, WHO activated in response to this new fact its global influenza laboratory network to perform tests about the disease. Based on the laboratory tests results, the suspicion of a form of influenza, including an H5N1 avian influenza, was replaced by the presumption of an unknown severe respiratory disease designated as an "atypical pneumonia." Analyses in China were negative about influenza. Later in the process, anthrax, pulmonary plague, leptospirosis, and hemorrhagic fever were also eliminated as possible causes of the disease. The fact that patients did not react to antibiotics caused investigators to think that the causal agent could be a virus, and this track was further investigated until the novel coronavirus was discovered.

Finding the cause of the disease (in this case, a new coronavirus) and obtaining enough evidence that this virus caused SARS were the primary tasks of the virology network. The identification of the causative agent was essential in preventing further international spread and developing emergency plans. (53 p. 1730) First, such identification could result in the production of diagnostic tests to facilitate the early identification, isolation, and treatment of patients, without researchers' having to rely exclusively on case definitions. Second, it would allow a better clinical management of patients with the use or development of adequate drugs. Third, and on a longer time horizon, it could lead to the development of a vaccine. Finally, virology discoveries would also help epidemiologists enhance their understanding of the origin of the disease, its incubation period, its infection rate, and its transmission patterns. A further step would be to discover where this virus came from. Although research determined that particular animals were a reservoir of the virus, as of today, it has not been shown whether the virus is animal or human in origin. Progress toward identifying the virus was the result of the collaborative work of different partners in the virology network (Germany, Singapore, Hong Kong, the Netherlands, and the United States) that further built knowledge based on the findings of their colleagues. (53 pp. 1731–1732) The network stimulated research and accelerated medical discoveries regarding the virus type and characteristics.

The exposure assessment consisted of estimating how humans could be exposed to the virus and with what effects, and resulted in the conclusion that the groups at risk were health-care workers and other individuals who had close contact with the patients, mainly in households. The populations at risk could not be precisely estimated due to the lack of sufficient and relevant data, but the ability of the disease to kill quickly and the rapid international spread indicated that world populations could generally be at risk, in particular, health-care personnel. In the risk assessment, the case fatality ratio is an indicator of the severity of the disease, but should be interpreted with caution. The case fatality ratio remains approximate up to the point at which data are sufficient to provide a more reliable estimate and better knowledge about the disease is acquired. Computing it using only cases for which the final outcome – death or recovery – is known leads to overestimation, because the average time from onset of illness to death for SARS is shorter than the average time from onset of illness to recovery (68).

Based on our calculations, the effective case fatality ratio was around 3% when the alert was given, about 8.5% when the coronavirus was identified, and steadily increased until it reached the reported 9.6% at the end of the outbreak. This effective case fatality ratio can be compared to WHO estimates that ranged from 4% on March 25, to 6%–10%, and finally 15%, the last revised estimate published by WHO during the crisis. Even heavily affected countries such as Vietnam continued to exhibit this average ratio. This difference was explained by the immediate and consistent application of infection control measures to contain the disease and by the persevering work of the field teams in close cooperation with local health-care staff and authorities in order to ensure the better possible treatment for the patients. However, age and general health condition would later prove to be important risk factors in the death of patients as well.

By tracing the cases and working on the identification of the index case (first case), the epidemiology network established that the virus could travel by air, which was a determining factor in the issuance of the March 15 travel advisory that was mainly intended to limit the spread of the disease. Also, it was investigated whether the virus could be transmitted by feces in air sewage (69 p. 122) after a certain number of cases appeared in the same block of flats in Hong Kong, or through air conditioning in a hotel in Hong Kong. It was determined, for example, that the disease was less contagious than influenza, generated fever, and presented a relatively short incubation period, which rendered control measures such as isolation and quarantine more effective at early stages of the epidemic when the number of cases was less important. (70 p. 1969) It also led to temperature checks that were applied in airports (e.g., in Singapore) and in the streets (e.g., in China).

Dose-response or cause-effect assessment depends on the amount of exposure necessary to cause the disease. Is the small quantity of virus diffused while talking sufficient to infect the other person engaged in the conversation? This aspect was difficult to establish, for knowledge of the disease was progressing at the same time that the outbreak was developing. The cause-effect or dose-response relationship remained unclear until the very end of the outbreak, but it was suspected that SARS could be transmitted easily from human to human by droplets,[31] which led to additional precautions in dealing with patients. The key factor was that the hospital staff seemed to be the group at highest risk, accounting for 20% of total reported cases. (71 p. 7) It later appeared that members of the health-care staff were often not aware of the risk and/or were not taking adequate protection measures when dealing patients suffering from SARS. The clinicians' network was instrumental in gaining knowledge about the symptoms and linking them with the epidemiological factors to improve protection for the hospital staff. For example, WHO issued a series of guidelines to improve the handling of SARS patients in hospitals and to decrease the risk of health-care personnel's catching the disease.

Risk characterization should result in a risk estimate derived from the calculation of a risk, such as the number of people who could catch SARS in a particular population. This phase can give rise to a quantitative result mostly in the form of a probability or to a qualitative result expressed by scenarios. The reproduction number, defined as the average number of secondary cases generated by one primary case in a susceptible population, is one measure of the risk of an infectious disease in terms of potential spread and consequences among a population. The basic reproduction number of a known disease such as influenza measures the risk and drives the measures to be taken to limit the spread of the disease. The effects of control measures reduce transmission, resulting in an effective reproduction number that decreases relative to the basic reproduction. Once the effective reproduction number passes below 1, the epidemic is considered to be contained. Therefore, the reproduction number is simultaneously an indicator of risk and an indicator of the effectiveness of the measures taken to control the risk. If experts agree that the reduction of the reproduction number is a key measure for evaluating the effectiveness of intervention measures, (70, 72, 73, 74) they also recognize that complete and accurate data need to be available, and that the models used to predict the transmission potential of a disease need to be further developed.

Spread-modeling studies were completed during the course of SARS with the first results published on line on May 23, 2003, by two teams, one from the Harvard School of Public Health and one from the Imperial College. Both gave a reproductive number of R_0 between 2.2 and 3.7 – Lipsitch's team of 2.2 to 3.6 with an average of 3.0 (excluding superspreading events) (70 p. 1967) and Riley's team of 2.2 to 3.7 with an average of 2.7 (including superspreading events). (73 p. 1963) It was the first quantitative assessment of the risk of the epidemic and of the effectiveness of control measures. These results could lead to optimistic conclusions about the transmissibility of the disease compared to influenza (R_0 around 10) or measles (R_0 between 15 and 20*),* but both studies agreed that the SARS infectious agent could provoke a pandemic if no control measures were implemented. For Lipsitch's team, the relatively low value of R suggests that an achievable combination of control measures – including shortening the time from symptom onset to the isolation of patients, and effective contact tracing and quarantine of exposed persons – can be effective in containing SARS. Indeed, such measures appear to have formed the basis of effective control in Singapore and Vietnam and have, on a smaller scale, likely contributed to the prevention of major outbreaks in other countries.

Wallinga and Teunis (74) have proved that timely alerts, coupled with the rapid and consistent implementation of control measures, have prevented approximately three-quarters of all potential secondary infections of SARS. Their major contribution has been to show that the reproduction number decreased from about 3 before the alert to 0.7 after the WHO alert of March 12, 2003, for regions in which infection had been introduced in late February 2003 (in particular Hong Kong, Vietnam, Singapore, and Canada showed a higher reproduction number) (74 p. 512).

The three teams agree that in the absence of such effective measures, SARS can spread widely, independently of its initially low reproduction number. It could easily spread and become endemic, like AIDS. Nevertheless, the intervention measures are costly and not sustainable over the long run for most public health infrastructures. Lipsitch's team insists that considerable effort is necessary to implement such infection control measures in settings where transmission is ongoing, but that such efforts are essential to quell local outbreaks and reduce the risk of further global dissemination.

Although the studies of Lipsitch et al. and Riley et al. were conducted using data gathered in selected areas at early stages of the spread of the disease with a history of about two months, they provided an estimate of the risk of SARS that can be used to design control measures, and also to evaluate their effectiveness. In addition, these studies suggest that modeling the geographical spread of an epidemic is possible if the reproduction number is known, (75 p. 81) which requires that the disease be known and that sufficient data are available.

In the case of SARS, the reliability and relevance of modeling studies results remained fragile due to the quantity and quality of data available. The studies refined their results once the outbreak was over. WHO set up a modeling group, bringing together ten institutions on a secure website during the SARS outbreak, but it remained unclear whether these estimates of the reproduction number were made available to WHO before Pr. Anderson and Pr. Lipsitch presented the results of their modeling studies at the first global meeting on the epidemiology of SARS, which was held at WHO in Geneva on May 16–17, 2003. (76 p. 26) This suggests that a major concern of WHO was whether such models can serve to better assess the risk and to implement adequate control measures, as well as to adjust the response to the evolution of the reproduction number.

Uncertainty reduction. WHO mechanisms to reduce uncertainty and improve risk characterization were essentially information based. New cases and new outbreaks were reported by countries or other sources, which indicated the spread of the diseases and the acquisition of knowledge through the newly set up communication forums, leading to such advances as the identification of the hazard. Proceeding to the SARS risk assessment was particularly challenging due to the high level of uncertainty that experts were facing and the initial lack of cooperation, and therefore a lack of information, from China. At the beginning of the outbreak, the disease was completely unknown. It could not be related to any familiar disease (e.g., influenza or pneumonia). Before the global alert of March 15, 2003, SARS was an unknown infectious disease that was probably airborne transmissible, presented a high case fatality ratio of around 10%, and for which no vaccines or effective treatment existed. (40 p. 3115) WHO knew that it could be transmitted easily and could kill quickly. The organization mostly applied a scenario approach to handle the high level of uncertainty. It essentially worked on a worst case scenario in which SARS could turn into a pandemic with a significant impact on human health and human lives worldwide, but which did not provide a range for the magnitude of these expected effects. In this perspective, the establishment and follow-up of epidemic curves, case fatality ratios, and contact tracing were essential tools in the risk assessment. WHO also heavily relied on scientific research to find the cause of the disease so that the measures could be more effectively targeted.

WHO and areas such as Vietnam and Hong Kong that were initially affected lacked information about the "atypical pneumonia" in the Guangdong Province. Although the relevant health authority conducted an expert investigation, its report, dated January 23, 2003, apparently circulated to a limited audience that included neither WHO nor Hong Kong authorities. (77 chapter 3, p. 14) This report pointed out the possibility of a new disease of probable viral origin and provided information about its epidemiology, clinical features (such as an average incubation period of 4 days in a range of 1 to 11 days), treatment, preventive measures to limit its spread (early detection and notification, isolation of patients, protecting health-care staff with masks and hand washing, and communication within the province to enhance intensive care structures). (77) Knowing that Guangdong Province had a low case fatality ratio of 3.8%, (78 p. 1115) could have helped improve clinical and epidemiological measures more quickly. There is no evidence that this information was made available to WHO experts during the field mission in the Guangdong Province undertaken between April 3 and April 5, 2003, although case definitions were updated following that mission.

Before the issuance of the global alert, uncertainty was mainly due to ignorance about the disease, as shown in Table 2.2, which illustrates the balance between facts known and unknown by WHO:

Table 2.2 Balance between known and unknown facts for SARS

Known	**Unknown**
Severe respiratory disease caused by a virus, also referred to as "atypical pneumonia"	Causative agent of the disease (bacteria, virus, chemical or biological agent from terrorist origin)
Potential for rapid international spread	Transmission (close contact, airborne transmission, environmental contamination ...)
Potential global impact	Magnitude of impact (burden on health systems, number of deaths, economic and social costs)
Highly lethal	Case fatality ratio
Symptoms	Infection rate, incubation Cure, treatment (medicine, vaccine)

After an assessment by WHO teams in Hanoi, Hong Kong, and Beijing, Dr. Heymann, Dr. Ryan, and Dr. Rodier from WHO were concerned about the similarities in the clinical aspects of the patients hospitalized in Hong Kong and Vietnam, and concluded that the disease qualified as a public health emergency of international concern. (79) These conclusions led to the Director-General's issuing the first global alert about an atypical pneumonia on March 12, 2003. This alert said that "no link has so far been made between these outbreaks of acute respiratory illness in Hanoi and Hong Kong and the outbreak of "bird flu" H5N1 in Hong Kong," in fact, clearly showing that WHO was considering the possibility that the Vietnam and Hong Kong outbreaks were linked to the atypical pneumonia reported in Guangdong.

In terms of risk assessment, the major difference between the alert of March 12 and that of March 15 was the evidence that the disease could spread internationally by air travel, which constituted a key reason for issuing the emergency travel advisory. (41 p. 78) On March 15, WHO had received reports from seven countries with declared SARS cases: Canada, China and Hong Kong, Indonesia, the Philippines, Singapore, Thailand, and Vietnam. (80) In addition to difficult internal discussions, to complete the evaluation of the risk of spread (41 p. 78) urgent teleconferences were conducted among WHO headquarters, regional offices, and Singapore, (34 pp. 15, 101) as well as with contacts in Hong Kong and Vietnam, to discuss the situation. Any link that could be established between air travel and the spread of this mysterious and lethal disease would involve substantial repercussions for the travel and tourism industry. In addition to the international spread of the disease, the following factors also influenced positively the issuance of the second global alert (81): the uncertainty about the possibly high potential of transmission of the disease, the fact that health workers were particularly at risk, the inefficiency of the drugs administered to patients, and the proportion of patients who had suffered respiratory failure.[32] The result of this risk assessment was that this disease was probably new, highly pathogenic, transmissible from person to person, and had the characteristics to become the first severe new disease of the twenty-first century with global epidemic potential, (53 p. 1730) although no one could predict its magnitude. Therefore, WHO determined that the world should be warned, and issued the second global alert on March 15, 2003. The next day, this travel advisory was followed by the issuance of case management guidelines aimed at supporting hospitals in affected countries in order to better protect health-care staff.

The identification of the causative agent at the end of March 2003 reduced uncertainty about the disease, but did not eliminate it. At this stage, it still remained unclear how the disease had developed and where it had originated. A hypothesis led to animal reservoirs, but no evidence could be found to confirm it. In the clinical field, the virus was identified, but diagnostic tests were insufficient and no treatment appeared to be efficient, so that about 10% of patients died. On April 16, 2003, WHO summarized the remaining uncertainties: “It cannot be predicted when this [SARS] outbreak will end but the world is on high alert, is better prepared and is acting in a true global alliance to protect the health of the world’s population against a threat of as yet unknown dimensions.” (50). In May 2003, the causal chain was partially identified, and experts attempted to provide some estimates about the reproductive number and the case fatality ratio.

As the level of uncertainty remained significant during the outbreak, the risk assessment was a continuous process in which experts relied on the latest experimental and empirical studies to increase their knowledge about the disease, establish the causal link, and propose measures. Uncertainty remained after the outbreak was declared over. The networks that had contributed to rapid progress in knowledge about the disease during the outbreak also continued to work on SARS after the outbreak. Numerous articles were published in the second half of 2003 and in 2004 about the epidemiology, virology, and clinical aspects of the disease. Research in areas that remained uncertain, such as the origin of the disease, its transmission modes, and its treatment has been undertaken, as has the development of drugs and the tests for the production of a vaccine in the coming four years (69).

Even at the end of the outbreak, the SARS risk did not qualify as a "known risk." The initial host of the disease and how it had developed remained unknown. Superspreading events were supposed to be caused by individuals who were more infectious than others, and the probability of SARS to resurge remained difficult to establish. Knowledge had progressed, and risk can be more precisely estimated, thanks to studies such as the ones mentioned above on predictions of the spread of the disease. However, a resurgence of SARS remained a distinct possibility, and WHO and other experts were convinced that vigilance should be maintained given the capacity of the disease to spread and the lack of a cure and vaccine.

Epidemic risk assessment. Following the alert, WHO implemented a procedure for the daily reporting of probable cases, for which a standard format was provided to countries. This information was mainly sent by emails to the WHO Regional Office or the Headquarters for compiling and producing epidemic curves and making dynamic electronic distribution maps to serve as bases for the analysis. This database remained confidential, and member states did not have access to it. The WHO headquarters posted situation updates and reports of the accumulated number of cases on a daily basis on its website. Based on these data, WHO assessed the risk of epidemic and international spread, and classified countries by level of risk based on the pattern of local transmission. (34 p. 69) For each country in which an outbreak was verified and/or for each country that reported SARS cases, WHO assessed the local transmission level, assigned a rating, and published the list of affected areas on its website. An area or a country would be rated as low (imported SARS cases with one generation of local cases), medium (more than one generation of local cases among identified known contacts of SARS cases), high (high transmission pattern with local cases occurring among persons who had not been contacts of SARS cases), or uncertain (insufficient information available to specify areas or extent of local transmission).[33]

WHO's first published list on March 16, 2003, included China (Guangdong Province, Hong Kong), Vietnam (Hanoi), Singapore, and Canada (Toronto, Vancouver) as affected areas. (82) This system was refined during the SARS crisis to indicate the recent local transmission of the disease.[34] Recent local transmission has occurred when, within the last 20 days, one or more reported probable cases of SARS have most likely acquired their infection locally, regardless of the setting in which this may have occurred. Accordingly, on May 2, 2003, WHO reclassified the "affected areas" as "areas with recent local transmission" (34 p. 262).

WHO's criteria for assessing the risk to international public health were the magnitude and the dynamics of an outbreak, including both the number of prevalent cases and the daily number of new cases; the extent of local chains of transmission; and evidence that travelers were becoming infected and were exporting the disease to other areas, possibly seeding an outbreak in those other areas. (83) Epidemic curves, case fatality ratios, and risk maps based on contact tracing were the main sources of information used for the risk assessment. Travel advice was issued on the basis of this set of epidemiological criteria, including the risk rating allocated to an area by WHO. Starting on May 10, 2003, the risk rating list included a link with the travel restrictions; regions or countries for which WHO recommended, as a precautionary measure, that all but essential travel be postponed were marked with a distinctive symbol. These travel advisories were reassessed every three weeks, a period that corresponded to twice the incubation period of SARS.

Information reporting was crucial to the risk assessment, but difficult for WHO to obtain. China, one of the most affected areas, began to cooperate only late in the process, while Thailand's delay in providing information to avoid the economic impact, mostly in the tourism sector, did not prevent it from being rated and included in the list. Canada provided incomplete and incorrect information, revealing inadequacies of the public health system and hospital sector in Ontario, as well as problems arising from an unclear division of responsibilities among federal, provincial, and territorial authorities. (84 p. 378) In addition, Canada (Toronto) strongly complained about the fact that it had not been informed of the WHO decision to put Toronto on the affected areas list before the information was made public. However, WHO had extended its travel advisory to Toronto on April 23, 2003, after the Ontario government had declared SARS a provincial emergency on March 26, 2003, and emergency plans had been activated in hospitals to suspend nonessential services and concentrate on the SARS outbreak. (85 pp. 63–71) WHO decided to include Toronto in the travel advisory based on the facts that the outbreak was growing and had affected groups outside the initial risk groups of hospital workers, their families, and other close person-to-person contacts, and that a small number of persons with SARS who had traveled to other countries had acquired the infection while in Toronto.

WHO used this transmission risk assessment as an incentive-based strategy to foster cooperation. It considered a lack of information about a country, a reluctance to provide, or a delay in providing this information as in itself a risk indicator. Information was sometimes shared on a confidential basis if the context had high political or economic impact. Countries therefore had an incentive to limit their risk by cooperatively providing adequate and timely information, reducing the potential economic impact of any travel restrictions.

Information sharing and communication. In addition to structures such as the GOARN, or the Global Influenza surveillance program (investigation and data reporting) – which played an important role by sending experts for field assessment missions, laboratory testing, and reporting activities – WHO set up new technology-enabled structures to better inform the risk analysis process, that is, virtual networks of experts and ground rounds. These ground rounds were video conferences and phone conferences organized at regular intervals that gathered experts, WHO personnel, field mission participants, consultants, and local and national authorities to share information and determine the next steps. The WHO regional office SARS task force organized daily meetings for all team members and for human resources planning and logistics, as well as teleconferences with all country teams and Headquarters. It also held weekly meetings with WHO teams in affected countries, with three global groups of technical experts (epidemiological, clinical and laboratory), as well as separate teleconferences with WHO representatives in Asian countries, Pacific countries, and countries not directly affected by SARS, and with senior WHO management at Headquarters and in the five other regional offices (34 p. 60).

This new mechanism operated at the global level in a cooperative and participative manner, enabling real-time sharing of data and experience about SARS on a worldwide basis. These ground rounds were not only privileged channels of communication that coordinated responses by guaranteeing that all participants would receive the same content and level of information, but they were also key instruments in assessing and reassessing the risk of SARS in light of the stream of new information. For example, concerns about travel advisories were discussed and reassessed within the WHO teams through global teleconferences conducted every evening. (86) These videoconferences provided valuable information for WHO's risk assessment of the situation of a region, a country, and globally, and their results served as basis for the issuance of WHO reports and guidelines.

The advantages of these ground rounds were that they made possible more transparent and complete information that was updated in real time and equally shared among participants. The challenges of such a system were to avoid routine or the presence of people who were not adding value or were even slowing down the process, in order to keep the teams motivated and moving ahead with the latest knowledge. Rivalries among teams of experts were difficult to manage in order to ensure that all information was adequately disclosed, a prerequisite for planning the most appropriate measures (see discussion above regarding the dispute over the merit of the discovery of the coronavirus). Although this innovative global risk governance mechanism was less than perfect, subject as it was to certain technological problems and occasionally being overwhelmed, it still served to combat a disease that could affect all countries.

WHO also organized international meetings during the outbreak to work on SARS risk assessment. WHO had already organized international consultation meetings, but these were generally part of a consultation process that was not done in an emergency situation. In collaboration with FAO and the World Organization for Animal Health (OIE), WHO gathered a meeting of concerned scientific experts in Madrid on May 8–9, 2003, to exchange information about the survival of the virus and further investigate the potential modes of transmission of the SARS virus. Until that date, it was believed that its most important mode of transmission was close personal contact, in particular exposure to droplets of respiratory secretions from an infected person. (87) After reports on the cluster of SARS cases in an apartment block in Hong Kong, sewage was believed to have played a role in transmission.

In addition, a potential risk for infection by ingestion (food and water) had to be assessed. On April 11, 2003, WHO did not prescribe any measures on its website related to goods, products, or animals, since these were not considered as posing a risk to public health. WHO nevertheless invoked as a precautionary measure the need to reinforce procedures to ensure food worker hygiene, including active assessment for diseases. (87) Finally, the group of experts gathered in Madrid was organized into a research network, as part of the international effort to coordinate the collective scientific understanding of SARS. The purpose of the meeting was to prevent SARS from becoming endemic and to agree on a research agenda, including studies on the resistance, persistence, and inactivation of the virus under conditions commonly found in food and water processing, as well as sanitation and sewage treatments and studies related to fecal-oral transmission.

The first global consultation on SARS epidemiology was held at WHO headquarters in Geneva from May 16 to May 17, 2003, and it brought together in person and via video and audio linkage more than 40 leading epidemiologists from 16 countries, including representatives from all areas experiencing significant outbreaks and from WHO teams at these sites. (52) This meeting aimed at sharing the experience of representatives of the centers (institutions, national and regional public health authorities, and other health protection agencies) that had dealt with outbreaks of SARS, as well as leading international experts in the fields of public health and communicable disease epidemiology, mathematical modeling, and clinical virology (76 p. 2).

In terms of risk assessment and adaptation of the global response to SARS, the objectives of this meeting were to understand the dynamics of SARS transmission and to evaluate the appropriateness of recommended measures of control. In the plenary session, the participants presented data on incubation period, infectious period, case-fatality ratios, routes of transmission, exposure dose and risk factors of transmission, the presence and significance of subclinical information, reproduction number in different transmission settings and under different control strategies, and animal and environmental reservoirs. (76 p. 2) A smaller group consisting of the WHO secretariat and external experts synthesized the discussions into a *Consensus document on the epidemiology of severe acute respiratory syndrome (SARS)*[35] that specified the current stage of knowledge about the SARS disease, the recommended control measures, and areas for further research. (50) It also provided member states with a basis for establishing preparedness plans to ensure that infrastructure and mechanisms were in place to prevent an outbreak should a case be imported (50).

The conclusions of the meeting were that there was no evidence that persons without symptoms had transmitted SARS to others and no evidence that SARS had an animal host or reservoir in the environment.

The pattern of outbreaks in different countries was similar, and the measures proposed by WHO showed consistent effectiveness. These measures included identification and isolation of patients, contact tracing, management of close contacts by home confinement or quarantine, and public information and education to encourage prompt reporting of symptoms. At this stage and based essentially on data provided by China, Hong Kong, Taiwan, Singapore, Vietnam, and Canada, the overall case fatality ratio was around 14% to 15%, and seemed to vary greatly according to age, sex, and general health condition of the patients (76 p. 11).

Based on these revised risk assessment results, WHO updated its recommendations in the *Definition of a SARS Contact in Management of Contacts of Probable SARS Cases*, (88) in a web document dated April 11, 2003, to include new facts about transmission such as precautionary recommendations in confined spaces and revised information about incubation and infectious periods. (89) In addition, WHO continued to be in charge of coordinating research on the transmission of SARS, reviewing guidelines for hospital cleaning and disinfection, conducting case studies of individuals who appeared to make a special contribution to the spread of SARS, supporting modeling studies to better assess the impact of control measures, analyzing the case fatality ratio for health-care workers, and coordinating further international collaborative research on SARS (81).

This meeting consolidated WHO's position in organizing international collaboration and showed the ability of the organization to deal with the global risk of SARS. The conclusions of the meeting were that the response put in place by WHO was appropriate and that the measures proposed for case management (health care), containment (identification and isolation of patients, vigorous contact tracing, management of close contacts by home confinement or quarantine, advisories of travel restrictions) and communication (public information and education to encourage prompt reporting of symptoms) were effective. This meeting also helped feed the risk assessment process with additional questions about the characteristics of the disease. Although the disease had stopped its progression, WHO continued to assess risk in order to be ready in case it should come back.

2.1.3.3 Cost analysis

It was not made public whether WHO proceeded to in-house evaluations of the total cost of SARS to worldwide economies as part of its risk assessment. However, WHO cited total SARS cost estimates resulting from studies done by others as ranging from USD 11 billion to USD 30 billion.[36]

In April 2003, WHO publicly referred to the estimated cost of USD 30 billion for the SARS disease, (90 p. 2) and to figures published in the *Far Eastern Economic Review* in April 2003 that estimated initial SARS-related damage to Far East GDP growth at USD 10.5–15 billion.[37] These computations included the economic effects due to the decrease of retail consumption, as well as trade activities and tourism. In comparison, this amount was close to the annual donor spending necessary to significantly reduce the global infectious disease burden in the poorest nations, and the yearly budget of WHO was around USD 800 million (90 p. 2).

Different organizations and academic institutions used modeling techniques to estimate the economic impact of SARS on GDP in Asia. These models mostly presented two scenarios that differentiated themselves by the expected duration of the SARS outbreak and the corresponding expected duration of the shock to the economies ("low scenario" SARS lasts about one quarter, and "high scenario" SARS lasts about two quarters). The cost expressed in GDP loss varies from 0.5% to 3.0% in the upper scale of the "low scenario" and from 1.5% to 4.0% in the "high scenario" according to the different studies. While the figures differ due to the varying assumptions made and the methods of computation applied, they all represent a significant amount of loss (mostly expressed in GDP loss in percentage to allow comparisons) for the areas affected by SARS. East Asian economies are particularly affected, but these studies show that the economic impact is global, affecting, for example, American and European countries as well. These financial estimates remained "best estimates" based on the available information at the time and subject to the assumptions made. The major driver of these analyses was the loss in confidence that the SARS crisis generated among the public on a worldwide basis. Although Asian economies had been vulnerable in the first half of 2003 due to the effects of the terrorist attacks in Bali and the start of the war in Iraq on March 19, 2003, SARS further eroded confidence in financial markets, as well as in tourism and consumer activities. In addition to the estimates of USD 11 billion and USD 30 billion, the Asian Development Bank foresaw an income loss ranging from USD 12.3 to 28.4 billion for East and Southeast Asia as a whole under two scenarios (SARS lasts through the 2003 second quarter or third quarter), in which Hong Kong and China represented about 43% of these losses under both scenarios.[38] The largest impact was in most cases on Hong Kong and China and was rather due to the effect of the SARS disease on the behavior of many people within the economies than to the disease itself (92 p. 129).

The estimated SARS cost of USD 30 billion in relation to the 8,096 reported SARS cases resulting in 774 deaths could be regarded as high compared to other diseases, such as tuberculosis, which killed 1.7 million people for 9.2 million new cases in 2006. (93) However, experts agree that the total cost might have been far higher, and models have been further developed to evaluate the cost of a future pandemic as a point for comparison. For example, a "small" influenza that infects 0.5% to 1.0% of the population (compared to 2% to 3% for SARS and around 25% for the 1918–1919 Spanish influenza), resulting in up to 65 million people infected and lasting around two to three years, would generate economic losses of USD 1 to 2 trillion dollars per annum based on 2005 GDP data (Asian GDP loss of USD 150–200 billion). (94 p. 23) Therefore, one can conclude that the measures enabling containment of the SARS outbreak in about three months on a worldwide scale were cost effective.

Comparisons in terms of lives saved provide additional arguments for cost effectiveness. Although the means of transmission of AIDS and SARS are very different, they had a comparable basic reproduction number (R_0) of between 2 and 5, (95), which can let one think what could have happened had no measures been taken and had SARS become endemic, such as AIDS. Another parallel can be drawn with the case fatality ratio of the Spanish influenza, which resulted in a case fatality ratio in the United States of about 2.2%; Spanish flu in modern America would kill about 1.8 million people. (96 p. A03) In comparison, the overall case fatality ratio of SARS was 9.6%. Although the transmissibility of the disease was less important than for an influenza, it provides an idea of the number of deaths SARS would have been able to cause worldwide had no measures been taken to contain its spread. According to WHO, "[I]n retrospect, spending to get rid of the new public-health threat was infinitely more cost effective than having to apply resources continuously over time to control the disease. No further outbreaks occurred, neither in winter of 2003–2004 nor in the next one. If SARS had become endemic, the resources required to root it out would have been enormous, especially in the winter months, and the impact on the health system would have been incalculable" (34 p. 252).

Regarding public health costs, WHO had to assign a budget from its emergency fund to handle the outbreak and support the field missions, a fact that was not made public. WHO's intervention in the SARS outbreak required additional funding from agencies and the reassignment of available funds, to which donor governments responded quickly and generously. For example, the Japanese government's grant of USD 3 million (97 p. 76) covered logistic support and supplies for both affected and unaffected countries (personal protective equipment, including masks, collection materials for blood and respiratory samples, and internationally approved containers for shipment of samples).

WHO included in its risk assessment cost elements from other evaluations, suggesting that USD 30 billion represented the total cost of SARS. If the cost side was thoroughly investigated using different costing models and WHO openly referred to them, they were not further analyzed or compared to the total expected cost of the epidemic to justify containment action. The notion of cost per life saved was not applied, as the expenditures on SARS were for an emergency situation and not part of a long-term public health program.[39] Effectiveness was justified by the fact that the absence of these measures, which were more significant in terms of potential economic impacts than solely in terms of public health costs, would have led to a far more costly situation. While WHO has not measured this cost effectiveness in terms of human lives saved or economic costs saved, it has relied on analyses of the cost of a pandemic as a benchmark to estimate the costs of a far larger economic impact, up to USD 1–2 trillion dollars per annum, which could apply to a SARS pandemic as well.

2.2 SARS international response

WHO's international response to SARS was based on the new concept of containment that was applied after 2002. This approach to SARS aimed at sealing off opportunities for further spread, both within countries reporting cases and internationally, to support the overall objective of preventing SARS from becoming widely established as another new disease in humans. (98) WHO's international response to SARS in the form of recommendations and guidelines was organized around three main activities, case detection, patient isolation, and contact tracing, in order to reduce the number of people exposed to each infectious case and eventually to break the chain of transmission, both locally and internationally. (99) WHO's response also included the monitoring of research activities, extending support to affected countries, and communicating information to health authorities and to the public (100).

The four recommendations that put the world on alert until WHO declared the outbreak over in July 2003 are as follows:

- *March 12, 2003. WHO issues a global alert about cases of atypical pneumonia*. (79) The alert confirmed outbreaks of a severe form of pneumonia in Vietnam, Hong Kong, and the Guangdong Province in China, and recommended isolation of suspected cases.

- *March 15, 2003. WHO issues an emergency travel advisory.* (101) This recommendation declared SARS to be a worldwide threat given its rapid spread to several countries, and provided guidance for travelers, airline companies, and crews on how to recognize symptoms of the disease (defining suspected cases and probable cases). Travelers suffering from the symptoms were advised not to travel. Airline companies were instructed to report any passenger or crew member who was suffering from the symptoms to the airport health authorities, who would assess the situation.
- *March 27, 2003. WHO recommends new measures to prevent travel-related spread of SARS.* (102) This travel advice sought to reduce the international spread of the disease and recommended that airline passengers departing from declared affected areas be screened. It was complemented by recommendations to airlines on what steps they should take if they detected a suspected case of SARS during flight.
- *April 2, 2003. WHO issues new travel advice for Hong Kong and Guangdong.* (103) WHO recommended that persons traveling to the Hong Kong Special Administrative Region of China and to the Guangdong Province, China, consider postponing all but essential travel.

In addition, on May 28, 2003, the World Health Assembly adopted a resolution on SARS (48) urging state members to continue their efforts to control SARS, apply WHO guidelines, ensure transparent and complete cooperation, and foster communication. In parallel, a resolution on the revision of the IHR authorized WHO to verify unofficial sources that reported an outbreak of a disease, evaluate the seriousness of a reported risk, and lead field investigation missions. These resolutions represented a formal acknowledgement of the extensive actions undertaken by WHO during the SARS outbreak, and provided a basis for future WHO actions until the adoption and enactment of the IHR. Finally, these recommendations were accompanied by guidelines for clinical management and the handling of specimens, as well as by a list of reported cases and affected areas. These documents were available on WHO's website and provided the most up-to-date information about how to handle the cases and protect health-care workers from contracting the disease. The list of the number of confirmed cases published and the list of affected areas – based on countries' reporting – indicated which regions were riskiest based on the criteria of effective local transmission, which provided information about the evolution and the international spread of the disease.

2.2.1 Reduction of casualties

WHO measures taken to contain SARS contributed to reducing the risk of the disease, mainly by limiting its global impact. The limitation of the international spread, the rupture of local chains of transmission, and the decrease in the number of new cases, combined with a cost-effective analysis, were completed in a few months.

2.2.1.1 Spread limitation

The preservation of the global collective interest in the case of SARS includes the limitation of the geographical spread of the disease both locally and internationally. We evaluated the limitation of the international geographical spread of SARS by considering the evolution of the number of new countries affected by SARS. SARS was regarded as contained when the local chain of transmission of the disease was ruptured, which resulted in local containment but also prevented the contagion of additional regions. We studied the effects of two kinds of measures: recommendations aimed at limiting the international spread of the disease by acting on travel (mostly air travel) through the screening of passengers at the airports in affected areas and travel restrictions based on the risk assessment of the local transmission level. These two sets of measures were complementary insofar as they reduced the number of new SARS cases both locally and internationally, with local containment contributing to global containment and vice versa.

International spread of SARS. The map overleaf (97 p. 75) shows about 30 countries and regions affected by SARS, along with the total number of cases due to outbreaks of the disease and imported cases.

As shown in Figure 2.1, in absolute terms, China and Hong Kong were the most affected areas in a worldwide number of cases that remained small. China is considered as the epicenter of SARS, and the first case of SARS was retrospectively traced back to November 16, 2002, in the Guangdong Province. At the time that WHO made the decision for the first alert on March 12, 2003, the outbreak was regional: all reported cases were in China, Hong Kong, and Vietnam, and the suspicion was that they originated from the same disease. (34 p. 58) By March 15, 2003, new cases were identified in Singapore and Toronto (Canada), and on flight SQ25 from New York to Singapore (patient intercepted in Frankfurt, Germany), which showed that the disease had already traveled by plane. The first list of affected areas (areas with recent local transmission) was issued on March 16, 2003, and included Guangdong (China), Hanoi (Vietnam), Hong Kong, Singapore, Toronto (Canada),

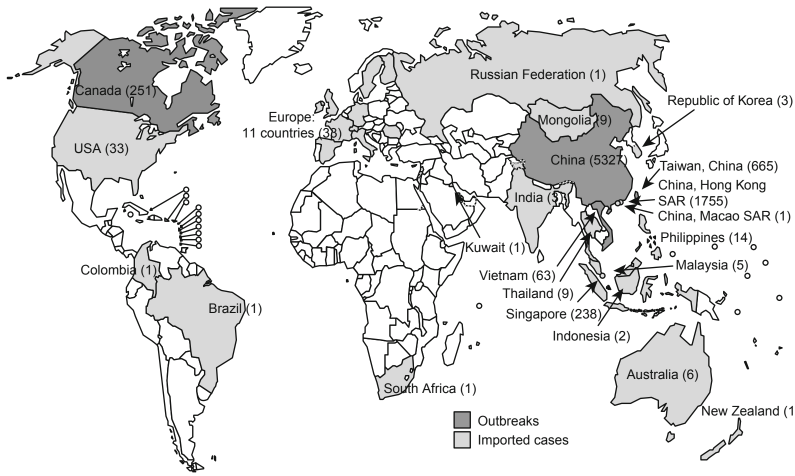


Figure 2.1 Probable cases of SARS worldwide, August 7, 2003

and Vancouver (Canada). Other countries have had SARS cases, but these remain imported cases with no local transmission (e.g., Germany).

Table 2.3[40] shows the evolution of the geographical international spread of the disease by country and date of reporting (case identification could have occurred earlier), indicating the presence of local transmission. Local transmission occurred when one or more reported probable cases of SARS most likely acquired their infection locally, regardless of the setting in which this may have occurred.

According to the table, major outbreaks occurred at the beginning of the crisis and for the most part before the second global alert of March 15, 2003, including the first travel recommendations. Of the eight areas with local transmission, three areas were infected by SARS before the March 12, 2003, alert and six before the issuance of the second global alert and travel advisory of March 15, 2003. Since March 15, only one major outbreak (Taiwan) occurred, and two other countries were added to the list of affected areas, but very few areas were rated "areas with recent local transmission."

Importation of cases continued, but the rapid development of international awareness about the risk and the implementation of infection control measures, coupled with a disease less infectious in nature than had originally been thought, helped limit the international spread and prevent local transmission. Of the about 30 areas or countries where imported cases were reported, only China, Vietnam, Hong Kong,

Table 2.3 International spread of SARS

Nr	**Area / Country**	**First formally reported case(s)**	**Local transmission**
1	***China***	***Feb-11-03***	***yes***
2	***Vietnam***	***Feb-28-03***	***yes***
3	***Hong Kong***	***Mar-11-03***	***yes***
4	Thailand	Mar-11-03	none
5	***Singapore***	***Mar-13-03***	***yes***
6	***Canada***	***Mar-14-03***	***yes***
7	***Taiwan***	***Mar-14-03***	***yes***
8	Germany	Mar-15-03	none
9	Switzerland	Mar-17-03	none
10	United Kingdom	Mar-18-03	none
11	Slovenia	Mar-18-03	none
12	United States	Mar-19-03	none
13	Spain	Mar-19-03	none
14	Italy	Mar-21-03	none
15	Republic of Ireland	Mar-21-03	none
16	France	Mar-24-03	none
17	Romania	Mar-27-03	none
18	Australia	Apr-01-03	none
19	Belgium	Apr-01-03	none
20	Brazil	Apr-03-03	none
21	Malaysia	Apr-05-03	none
22	Kuwait	Apr-10-03	none
23	South Africa	Apr-11-03	none
24	Japan	Apr-11-03	none
25	***Philippines***	***Apr-14-03***	***yes***
26	Sweden	Apr-14-03	none
27	Indonesia	Apr-14-03	none
28	***Mongolia***	***Apr-17-03***	***yes***
29	India	Apr-17-03	none
30	Bulgaria	Apr-24-03	none
31	Republic of Korea	Apr-29-03	none
32	Poland	May-01-03	none
33	New Zealand	May-02-03	none
34	Colombia	May-06-03	none
35	Finland	May-08-03	none
36	Russian Federation	May-31-03	none

Singapore, Canada, Taiwan, the Philippines, and Mongolia encountered local transmission. Countries with imported cases after March 15, 2003, were able to prevent outbreaks from happening in their communities or to limit their extent and duration. For example, Mongolia and the Philippines encountered small outbreaks that were quickly brought under control. After the SARS outbreak that began in Mongolia on April 17, no other area would suffer the same fate, which is only about one month after the issuance of the first global alert.

The communication about SARS outbreaks, the publication of the list of affected areas, and the application of airport screening recommendations[41] contributed to reducing the number of symptomatic persons with SARS traveling internationally and containing the international spread of SARS. After May 31, no new SARS case was identified in the areas known to have been affected – which is about 2.5 months after the issuance of the global alert. It was interpreted as a sign that the outbreak was now contained, although it was officially declared over only at the beginning of July 2003.

Travel restrictions effects. Since the screening of international travelers – by asking questions and possibly checking their temperature as they departed from areas with local transmission in the B or C rating (adopted on March 27, 2003) – did not prove to be effective in reducing the travel of infected persons from some of the affected areas and resulting in exportation of cases, WHO raised the level of alert by publishing the first travel restrictions against the Guangdong Province and Hong Kong on April 2, 2003. Since that date, travel restrictions have been reevaluated daily based on the results of the risk assessment and the determination of "areas with recent local transmission."

Table 2.4 shows the relationship between the risk rating of an area as an "area with recent local transmission" and the issuance of travel restrictions, and the lifting of these restrictions once the area has been declared free of recent local transmission. This table is based on the publication on WHO's website of issuances of travel restrictions (107) and a summary table of affected areas (105). The starting date corresponds to the date of onset of the first imported case, which is the case that most likely started a local chain of transmission. An exception is China, where the date of onset corresponds to the first identified case in Guangdong on November 16, 2003. The ending date is 20 days after the last reported, locally acquired probable case either died or was appropriately isolated (105).

There is a link between the risk rating and the travel restrictions. Once an imported case was reported, WHO evaluated whether the case remained limited or whether there was a chain of local transmission. Then, if there was a local transmission and therefore an outbreak, the area was classified as an "area with recent local transmission" with a rating of *A, B, C* or *Uncertain*. Finally, WHO issued travel restrictions for

Table 2.4 SARS travel restrictions

		Area with local transmission of SARS		Travel restriction	
Country	**Area**	**From**	**To**	**Issued**	**Lifted**
Canada	Greater Toronto Area	Feb-23-03	Jul-02-03	Apr-23-03	Apr-30-03
				May-26-03	Jul-02-03
Canada	New Westminster	Mar-18-03	May-05-03	none	none
China	Beijing	Mar-02-03	Jun-18-03	Apr-23-03	Jun-24-03
China	Guangdong	Nov-16-02	Jun-07-03	Apr-02-03	May-23-03
China	Hebei	Apr-19-03	Jun-10-03	May-17-03	Jun-13-03
China	Hong Kong SAR	Feb-15-03	Jun-22-03	Apr-02-03	May-23-03
China	Hubei	Apr-17-03	May-26-03	none	none
China	Inner Mongolia	Mar-04-03	Jun-03-03	May-08-03	Jun-13-03
China	Jilin	Apr-01-03	May-29-03	none	none
China	Jiangsu	Apr-19-03	May-21-03	none	none
China	Shanxi	Mar-08-03	Jun-13-03	Apr-23-03	Jun-13-03
China	Shaanxi	Apr-12-03	May-29-03	none	none
China	Tianjin	Apr-16-03	May-28-03	May-08- 03	Jun-13-03
China	Taipei	Feb-25-03	Jul-05-03	May-08-03	Jun-17-03
China	Taiwan	Feb-25-03	Jul-05-03	May-21-03	Jun-17-03
Mongolia	Ulaanbaatar	Apr-05-03	May-09-03	none	none
Philippines	Manila	Apr-06-03	May-19-03	none	none
Singapore	Singapore	Feb-25-03	May-31-03	none	none
Vietnam	Hanoi	Feb-23-03	Apr-27-03	none	none

areas that were classified *C* or *Uncertain*. On May 10, WHO indicated on its website that nonessential travel should be postponed to countries rated *C* and *Uncertain*, clearly showing the relationship between this risk rating and the travel recommendations. (108) China (including Hong Kong and Taiwan) was rated C (except for Inner Mongolia and Tianjin, rated "uncertain"), indicating that travel to China should be avoided, while Singapore, Canada, and the Philippines incurred no travel restrictions, thanks to their *B* classification.

However, being rated as "areas with recent local transmission" did not systematically lead to travel restrictions, since other factors are also considered in the analysis. On March 16, 2003, Vietnam and Singapore found themselves on the first list of affected areas, but did not face travel restrictions. In fact, both countries managed to rapidly limit the number of new cases and the local chains of transmission due to strict infection control measures. Hong Kong, however, which also implemented strict control measures, could not be easily contained because of its proximity to mainland China and the entrance of additional infected persons into its territory. Canada incurred travel restrictions at two stages of the outbreak mainly due to inadequate infection control measures that were put in place at the beginning of the outbreak, which allowed for contamination among different hospitals. The first travel advisory was nevertheless contested by Canada, which considered its outbreak to be under control. James G. Young and the minister of health and long-term care, and several other personages, made the trip to WHO headquarters in Geneva to argue that the travel advisory was inappropriate, but without success. (109 p. 37) In fact, a second wave of SARS cases soon occurred, peaking at the end of May, and as a result Canada landed on WHO's second travel advisory, in force until July 2, 2003.

Although the traveling of exposed or infected persons is considered to have been a major source of the spread of SARS, the effect of travel restrictions and airport screening of passengers remains difficult to evaluate. Initial studies suggested that travel directives were effective in limiting the international spread of SARS, highlighting the fact that implementing airport screening, early detection, and isolation and quarantine are very costly measures that are difficult to maintain over long periods of time and with an ongoing large number of new cases. (72 pp. 75–76) WHO estimated that protection measures limited in-flight transmission of SARS and showed that cases due to in-flight exposure were no longer being reported after March 27, 2003. Between March 15, 2003, and March 27, 2003, twenty-seven persons on 4 of 32 international flights carrying symptomatic persons with SARS appear to have been infected (one flight alone on March 15 accounted for 22 of these 27 cases), and these occurred before March 23. (110) The fact that the majority of the infections due to symptomatic persons traveling by plane occurred before March 23, 2003, may indicate that travel restrictions helped reduce the potential number of travelers from and to affected areas, and therefore helped reduce the number of infected persons and areas affected. The sensitivity to travel restrictions is evidenced by the way travel through Hong Kong International Airport rebounded once travel restrictions were lifted on May 23, 2003 (111 p. 243).

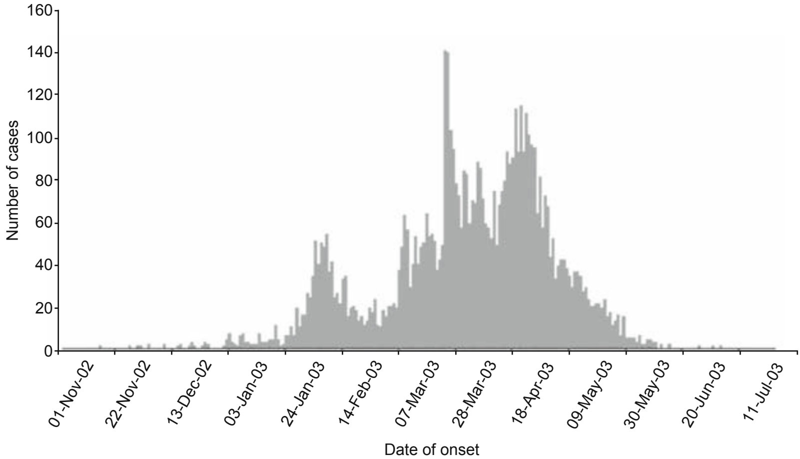
2.2.1.2 Impact on human health

The reduction in new cases of SARS indicated that the risk of a SARS pandemic had been lessened. The evolution of the effective reproduction number based on the measures taken could also provide an indication of the reduction of the pandemic risk. Since the evolution of the total number of cases depends on the rate of new cases per day, we assessed the effectiveness of the measures proposed by examining whether the number of additional cases decreased once the measures began to be implemented.

Evolution of the number of SARS cases. After the global alert of March 12 and the travel advisory of March 15, coupled with the issuance of case definitions, and as the global epidemic curve of SARS below shows, the number of new cases continued to increase, with the highest peak early in April before the trend fluctuated down and up again at the end of April, to finally decrease until the outbreak was declared over on July 5, 2003[42] (Figure 2.2).

Two main factors can explain this evolution. On the one hand, there are time lags between the issuance by WHO of alerts and recommendations, their implementation, and their effects, as well as the reporting of these effects. On the other hand, China and Taiwan – where reporting and measures were implemented later – encountered a significant increase in the number of cases up to May 2003, which significantly influenced the total epidemic curve. After April 2, once the four major WHO recommendations were issued and started to be implemented, the percentage of new cases decreased consistently right up to the end of the outbreak. After April 30, the additional number of cases stayed below 6%, varying between 0%–1% from May 13 onward. After June 2, new SARS cases were no longer reported.

The peak that was registered on April 2, 2003, with 419 new cases driving the travel advisory of April 2, can be explained as a response



This graph does not include 2,257 probable cases of SARS (2,521 from Beijing, China), for whom no dates of onset are currently available.

Figure 2.2 Probable cases of SARS by week of onset worldwide (n = 5,910), November 1, 2002–July 10, 2003

to a continuous export of the virus, spread at Amoy Gardens in Hong Kong and with further outbreaks in Vietnam and Singapore. There was evidence of an increase in the number of cases in Hong Kong and of the continuing travel of sick persons, as well as more precise information about the infectious characteristics of the newly discovered coronavirus. In addition, a local outbreak occurred in another Vietnamese hospital on April 3, 2003, and an increase of the number of cases among health-care workers and family members in Singapore contributed to the peak of this period. Case reporting of China also strongly influenced the epidemic curve in early April. On March 26, 2003, China reported 792 cases and 31 deaths from atypical pneumonia from November 16 to February 28, although it reported only 305 cases and 5 deaths up to February 9. China officially started daily reporting of probable SARS cases both nationwide and by province on April 1, and reported an increase of 384 cases from April 1 to April 2. This spike may have contributed to the increase of reported cases up to mid-April, although cases were supposed to be reported and classified based on the actual date of onset.

The measures prescribed to identify SARS cases and manage them through isolation and specific protection measures for health-care workers proved effective, although peaks in epidemic curves occurred after the issuance of the global alerts and the first travel advisories. According to

WHO reports, after the issuance of recommendations, all countries with imported cases (with the exception of provinces in China) were able either to prevent further transmission or keep the number of additional cases very low through prompt detection of cases, immediate isolation, strict infection control, and vigorous contact tracing (113 p. 2).

The first measures proposed by WHO were intended to reduce the spread of the disease locally (guidelines to protect health-care staff and persons close to the patients) and internationally (reduction of travel, detection, and isolation of cases). In fact, hospital staff constituted the primary population at risk, and the measures aimed at protecting them from catching the disease from their patients required some training before they could be implemented correctly and consistently. Case definitions and protection measures were regularly updated to integrate the latest findings of the collaborative multicenter, such as the cautious manipulation of respiratory systems. Early detection and isolation of patients were evaluated as positive measures to reduce the spread of the disease in light of the fact that no further transmissions of the disease beyond those initially identified were reported after March 24 (34 pp. 22–24).

For a more detailed analysis of the evolution of total SARS cases, the data of the following areas have been grouped into six graphs based on the cumulative number of reported suspect and probable cases of SARS that are available on the WHO website and that were published on a daily basis. (34 p. 80) These data include confirmed SARS cases of the "affected areas" or "areas with local transmission" based on the WHO case definitions.

Evolution of SARS cases in areas with local transmission. The application of WHO control measures helped reduce the number of new daily cases of SARS in areas with local transmission – China, Hong Kong, Taiwan, Singapore, Vietnam, Canada, Mongolia, and the Philippines – and achieve its worldwide containment by early July 2003. The evolution of the additional number of cases per day in the areas with local transmission for China, Hong Kong, Taiwan, Singapore, Vietnam, and Canada (Mongolia and Philippines were not analyzed, since these were outbreaks of minor importance) followed two trends, as shown in Figure 2.3.[43]

The first trend consisted of one wave of cases that was progressively brought under control (occurring in China, Hong Kong, Taiwan and Vietnam), while the second trend shows an outbreak in two waves (occurring in Singapore and Canada). These trends took place in different

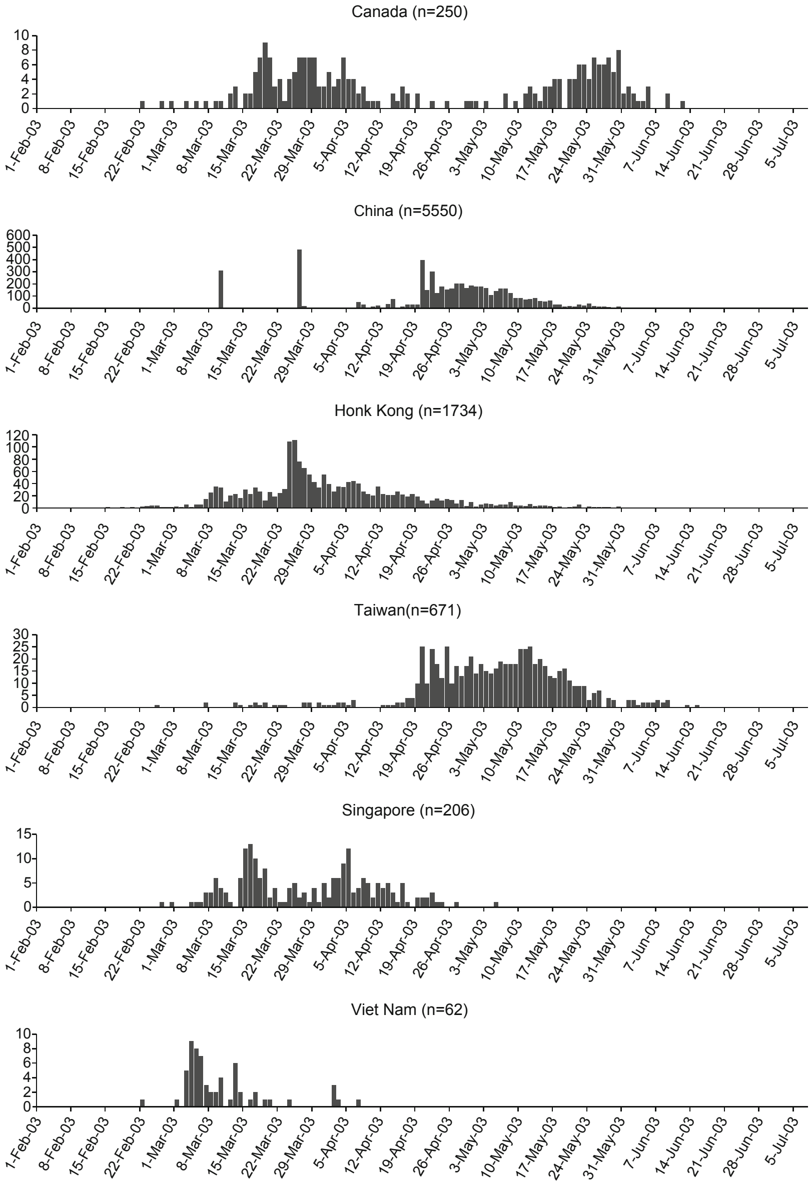


Figure 2.3 Evolution of SARS cases in areas with local transmission

transmission settings, but the rebounds in various waves did not undermine the capacity to finally contain the disease, although in particular cases it may have required more effort over a longer period of time.

Within the first group of countries, the evolution of the additional number of cases followed a similar pattern, but with a time difference attributable to the delayed application of the response in China and Taiwan. Although China's and Taiwan's[44] application of the response to SARS was delayed and China started to report cases only at the end of March, the overall pattern remains similar to the ones in Hong Kong and Vietnam. As the outbreak in Hong Kong was about to come under control, China's outbreak was growing fast and significantly. On May 12, 2003, about two months after the global alerts, while China was passing the cap of 5,000 cases (5,013 cases) with a daily increase of 129 cases (+2.6%), Hong Kong's new cases were decreasing overall from the peak of 155 additional cases reached on April 1 to 9 cases on that date. Hong Kong took measures as soon as the outbreak was declared and closely monitored the containment of the disease with the support of WHO.[45] China started to cooperate later in the process, but implemented larger scale, strong containment measures such as temperature checks, airport screening, isolation of patients, closure of public places, and quarantine. However, the last probable case of SARS in Hong Kong was recorded on May 31, 2003, as opposed to June 3, 2003, for China.

The containment of SARS in mainland China was critical to the global containment of the disease and the reduction of its global effects. WHO officials were concerned about the spread within the country and the cases that it could export worldwide. Hong Kong incurred new cases due to the proximity and exchanges with the Guangdong Province, a circumstance that contributed to the export cases abroad. Data for mainland China were incomplete, and the reliability of their reporting was questioned during the outbreak, which is reflected in the figure above with two isolated large numbers of additional cases. On February 11, 2003, 305 cases of "atypical pneumonia" had been reported by Guangdong health authorities that were later attributed to SARS. On March 26, the WHO team concluded that the Guangdong outbreak was an outbreak of SARS, which would be acknowledged as such by Chinese authorities on March 28, 2003, when it started to report cases to WHO. The global alerts and the travel advisories previously issued, designating China and Hong Kong as regions to be avoided, triggered significant economic consequences. These consequences and increased international pressure helped change China's attitude toward multilateral cooperation.

This date of March 28, 2003, represented a reversal of China's policy in three ways. First, it was a break with the previous reluctance to accept investigations conducted by international experts and WHO experts on Chinese territory. After weeks of being put on hold, a WHO mission was now authorized to investigate the outbreak in Guangdong. In all, around 80 experts from around the world intervened in China to assist WHO in its work. Second, it marked a complete change in conclusions about the source of the disease. China now accepted that SARS could be caused by a new virus. In fact, Chinese CDC officials announced that chlamydia was a source of the disease and maintained that position firmly, even though evidence inland and abroad was already challenging these results, which appeared to be difficult to combat for cultural and political reasons. Third, it marked a radical change in Chinese policy, which was that the SARS crisis would now be managed both internally and in cooperation with the international community. Finally, it triggered the resignation of high-ranking Chinese officials, including Health Minister Zhang Wenkang and Beijing mayor Meng Xuenong, who were accused of responding inadequately to the SARS outbreak on April 20, 2003, and the launch of a centrally led mobilization campaign to contain SARS in China. In the Chinese system, health is managed in the provinces, but from now on, strong direction would be coming from the central government.

Starting on April 1, China mobilized resources to contain the disease and worked in close cooperation with WHO, allowing different visits in various provinces and applying WHO recommendations. As a result of its visits, WHO concluded, for example, that the outbreak in the Guangdong Province had been appropriately managed, but that this was not the case in Beijing.[46] In Beijing, the detection of cases based on WHO case definitions had not been accurately and consistently performed, nor was hospital management and infection control. (34 p. 31) WHO also asked Chinese authorities to reexamine samples taken from victims killed by the SARS virus. (114) On April 23, schools were closed for two weeks, and on May 9, 2003, the State Council issued a new Regulation on Public Health Emergency Response to strengthen surveillance. (34 p. 84) Unlike other regions, in the Guangdong Province, infection control measures inside and outside hospitals had been implemented since February. Although the efficiency of masks has been questioned, people wore them in this province and, later in the outbreak, in other regions of China as well. Strict infection control measures have been applied, going even further than WHO's recommendations. This was reflected in the slowdown of new cases after the milestone of 5,000 cases was passed on May 12, 2003. After that date, the number of new cases increased less than 1% between May 14 and May 30, to reach 0% on May 31, 2003.

On the other hand, Vietnam and Hong Kong closely cooperated with WHO from the beginning of the outbreak. The fact that the outbreak was closely watched and documented by a WHO communicable disease specialist working in Vietnam, Dr. Carlo Urbani, helped make possible the early identification of the disease. Although the Vietnam outbreak involved a limited number of cases, the main increase in the number of cases occurred at the start of the outbreak, before the issuance of protection measures for members of health-care staff. Health-care staffers were particularly affected in Vietnam due to inappropriate case management actions that exposed personnel to the virus and contributed to a significant outbreak among this population. Due to the virulence of the outbreak in early March, a local team was assigned, with the approval of health authorities, to work with the GOARN experts who arrived on March 10 and 11. The next day, after investigating, these experts suspected that a new pathogen, not influenza, was the probable cause of the disease (34 p. 95).

Immediate implementation of control measures to prevent further transmission in hospitals, and surveillance for new cases, including contact tracing, was recommended. These measures were confirmed by the issuance of the global alert on March 12 after a teleconference with WHO Headquarters in Geneva to discuss urgent technical issues. These included case definition, case management and treatment guidelines, and the combining of information from the outbreaks in China, Hong Kong, and Vietnam. Vietnam agreed to cooperate with WHO's reference laboratories with respect to further testing related to the disease and to rely on international assistance in conducting research on the disease and the clinical management of hospitalized cases. It also assigned one hospital to the disease cases. On March 14, the Vietnamese government also established an interministerial steering committee and, following a WHO recommendation, a task force to manage the outbreak, which were privileged points for cooperation with the organization. The response to the SARS outbreak in Vietnam was an example of field cooperation, which on April 28, 2003, led to the removal of Vietnam from the list of areas with recent local transmission. Vietnam was among the first countries affected by SARS and the first to be removed from the list of affected areas.

The second trend shows outbreaks in waves that could still be brought under control in a relatively short time. Canada's health-care system has proven to be unprepared for such outbreaks, and the insufficient infection control measures taken at the beginning of the crisis failed to prevent the appearance of another cluster. While the first wave mainly concerned health-care workers, patients, and their visitors at four hospitals, the second wave primarily affected the workers and visitors of a single hospital ward. (85 pp. 66–67) Failure to provide information and contact tracing (with one patient not recognized as a SARS case) combined with inadequate case management (no isolation of the symptomatic case, which was then transferred to another hospital) was at the origin of this second cluster. With health infrastructures overwhelmed and patients being inadequately discharged, the communication problems and lack of human resources led on March 26, 2003, to the declaration of the provincial emergency in Ontario. The strict, if delayed, application of infection control measures helped contain SARS later than Singapore or Vietnam, which were also among the first countries to be affected by the disease.

Singapore suffered three intertwined waves of transmission, with peaks in the number of cases in mid-March and the beginning of April. It seemed that a few patients transmitted the disease among hospital staff and their community, creating clusters that accounted for the majority of SARS cases. Contact tracing and identification of index cases, as well as the application of stringent containment measures were key in containing the disease. The Singapore Ministry of Health formed a task force and cooperated with WHO from the beginning of the outbreak, accommodating the WHO field mission on March 21, 2003. Even before the issuance of the global alert, Singapore had already applied isolation measures and implemented quarantine at home for about 300 contacts who had been traced. (34 p. 105) Moreover, Singapore's containment measures went beyond WHO standard recommendations in both content and application. For example, certain community control measures involved contact tracing with the support of the army, mandatory quarantine at home and close surveillance, bans on hospital visits, and school closures, as well as measures affecting the management of health-care facilities that included the designation of dedicated SARS hospitals, isolation rooms, fever surveillance, and the use of complete protective equipment. Singapore even built a container with 130 wooden isolation rooms to accommodate SARS cases. To keep the population informed and disseminate measures that were to be respected, on May 21 Singapore also set up a "SARS Channel," a television station devoted exclusively to disseminating information about SARS. (34 p. 41) On May 31, Singapore was removed from the WHO list of affected areas.

Economic cost. Compared to the initial estimate of USD 30 billion, consumption of significant health-care resources and economic disruptions resulted in a total economic cost that was either lower (USD 18 billion) or higher (USD 59 billion), depending on the model applied. The total cost of SARS to Asian countries breaks down to over USD 2 million per person infected, (115 p. 39) a number derived from the total estimated cost of about USD 18 billion, using gross domestic product (GDP) as the measure of reference. The Asian Development Bank estimated total losses of USD 59 billion using total final expenditure (TFE) rather than GDP as the measure of reference, as TFE, which corresponds to the sum of domestic demand plus exports, was considered a more comprehensive measure of the impact.[47] In relative terms, Hong Kong and Singapore were the most heavily affected areas, while in absolute terms, China (except for Hong Kong) recorded the most important losses, representing about 30% of total losses, under both methods.

However, in 2008, a study of the economic impact of SARS revealed that its impact on affected economies was far smaller than had been suggested by contemporary media reports and model estimates. (116) In addition, current models used to assess the transmission potential of a disease and therefore to plan adequate intervention measures are not yet developed enough to include a cost comparison dimension of these measures. Finally, at the level of the organization, WHO's SARS budget and effective costs analyses were not made public, and therefore planned costs could not be compared with effective costs.

Although providing reliable and precise quantified estimates remains difficult, analysts agree that the costs of inaction (or of later or delayed action) would have been far greater both in terms of the ongoing health-care burden and the loss of human lives than the costs in economic disruption that countries did suffer from containment measures. One indication that the international response was appropriate in the case of SARS is arrived at by comparing the economic cost of the actions taken to contain the diseases to the estimated global cost of inaction. Preliminary estimates of the total economic costs were calculated during the SARS outbreak, and are provided in the section cost analysis above, as it constituted an important aspect in the risk assessment. In this section, the analysis pertains to final estimates computed on actual data once the outbreak was over, data that we treat as estimated effective costs of the outbreak for our analysis.

The total cost of SARS was considered to be lower than the total cost that would have been incurred had the outbreak lasted much longer, suggesting that the adequacy and timeliness of the measures undertaken shortened the duration of the outbreak. The fact that the longer duration might be caused either by delayed action or by a particularly high virulence of the disease that could resurge in waves was not discussed. If the outbreak had lasted more than one quarter, the cost would have been much larger, although estimates of the total impact varied. Rossi and Walker estimate that the economic impact of a similar outbreak lasting over two quarters of the year rather than one would probably be close to double the impact of SARS. (94 p. 21) But in the case of an extended outbreak, the economic impact should be larger than simply a multiplier of the SARS impact over one quarter, since it would have to include losses to nonessential trade and consumption, as well as secondary repercussions from the SARS impact that would increase the total estimated cost (94 p. 21).

In addition, the economic impact is related to the infection rate, suggesting that infectious diseases such as SARS, if not properly attended, could result in far more significant costs than what the effective costs of SARS actually were. *The World Health Report 2007* relied on Rossi and Walker's analysis to explain that, for infection rates of up to 1% of the world's population, one could expect a decrease in global GDP of 5%, with an additional loss of 1% per additional percentage increase in infection rate. (115 p. 39) Experts estimate that the resulting cumulative economic disruption would finally produce a shutdown of the global economy, (115 p. 39) which, fortunately, was avoided in the case of the SARS crisis.

Experts agree that SARS countermeasures had a cost (although they disagree on the final amount). But few analysts consider that inaction would have had a cost as well, and even fewer have tried to quantify it. In fact, inaction could have resulted in a new disease, SARS, becoming endemic (such as AIDS did, for example), or could have resulted in a pandemic of even larger scale. If SARS had proved the equivalent of the Spanish Influenza of 1918–1919, then losses would have been many times more than those seen in 2003, both in terms of human lives and economic impact. (94 p. 19) Rossi and Walker (94 pp. 21–23) established that pandemics infecting just 0.5%–1% of the world population (up to 65 million people) would probably see economic losses run from one to two trillion dollars per annum over a period of perhaps two to three years (based on 2005 GDP data). Such a small pandemic would represent a loss of 5%–6% of worldwide GDP, as compared to a Spanish influenza-like pandemic that could represent a loss of 30% of worldwide GDP (in 2005 terms) or over 10 trillion.

2.2.2 Cooperation and communication

WHO's four main recommendations were based on dialogue, were collegially decided, and were publicly communicated, as shown in Table 2.5.

From an internal point of view, the four above-mentioned decisions were the result of a dialogue among experts and not the deliberation of a single person. They were group decisions and were publicly communicated either by press conference or on the WHO website, or both. Consultation was internal with support groups of the task force such as infection control, clinical treatment, laboratory testing, public health measures, or travel measures, and was external to the networks of experts and national authorities in certain cases. The travel restrictions of April 2, 2003, were communicated to Chinese and Hong Kong authorities. Nevertheless, the travel restrictions were a bone of contention. Canada and the Philippines complained about the lack of transparency in the assessment of the level of local transmission that triggered the issuance of travel restrictions and about the fact that they were not consulted. They also questioned the lack of consideration of the economic impact of such travel restrictions entailed by the decision to issue such an advisory at a global level. As a result, the revised IHR 2005 included a consultation process between officials in the affected area and WHO as part of the formation of an appropriate international response to a public health emergency of international concern.

2.2.3 Response monitoring

WHO monitored the SARS response using the reporting of cases by national authorities. It ensured that WHO measures were put in place by following up on the number of cases and the observations made during field missions, issuing further recommendations if the original measures were not completely followed. Finally, WHO applied an incentive-based system to obtain cooperation and enforce recommendations.

2.2.3.1 Reporting system: a key monitoring tool

This SARS reporting system was a risk assessment and risk management tool. On the one hand, it allowed to follow-up on the development of an outbreak through the evolution of the increase of the number of cases, and assessment of the risk of further spread. On the other hand, it gathered information about SARS to follow up on the situation and take new or corrective action based on the analysis of this information. External and internal reporting, as well as information from both unofficial and

Table 2.5 WHO's four main recommendations about SARS

Recommendation	Consultation	Collegiality	Public communication
March 12, 2003: WHO issues a global alert about cases of atypical pneumonia.	Short consultation of experts and professionals in the field, WHO regional office, and Vietnam country office, as well as Vietnam and Hong Kong authorities.	Group decision[48] backed by Director-General (Dr. Heymann and members of his team; Dr. Ryan, head of GOARN; Dr. Rodier; and key personnel involved in the management of the outbreak in Vietnam and in Hong Kong).	Published on WHO website of Epidemic and Pandemic Alert and Response (EPR) within the media section.
March 15, 2003: WHO issues emergency travel advisory.	Short consultation of experts and professionals in the field, WHO regional office and Vietnam country office. No evidence of consultation of Vietnam and Hong Kong authorities at this stage.	Final decision by WHO Director-General based on group decision (Dr. Heymann, Dr. Rodier, and Dr. Ryan, together with Denis Aitken, senior adviser of the Director-General, and senior epidemiologists).	Published on WHO website of Epidemic and Pandemic Alert and Response (EPR) within the media section. Official and public message of the WHO Director-General: "This syndrome, SARS, is now a worldwide health threat. The world needs to work together to find its cause, cure the sick, and stop its spread." (80)
March 27, 2003: WHO recommends new measures to prevent travel-related spread of SARS.	Consultation of SARS task force, travel measures group and risk assessment group – Dr. Hardiman IHR Coordinator. Consultation of experts who are part of the collaborative virtual networks. No evidence of consultation of national authorities.	Group decision (Dr. Heymann, Dr. Rodier, and Dr. Ryan) and team members.	Published on WHO website of Epidemic and Pandemic Alert and Response (EPR).
April 2, 2003: WHO issues new travel advice for Hong Kong and Guangdong.	Consultation of experts who are part of the collaborative virtual networks. Consultation of SARS task force, travel measures group. Agreement of Hong Kong authorities during daily conference call with WHO team members of the SARS task force. No evidence of consultation of Chinese authorities.	Group decision (Dr. Heymann, Dr. Rodier and Dr. Ryan) and team members.	Published on WHO website of Epidemic and Pandemic Alert and Response (EPR).

official sources, was conveyed to the organization so that it could assess the risk and manage the outbreak. For example, the warning from unofficial sources initiated the verification and assessment processes. After issuance of the global alert, a formal reporting of SARS cases was put in place, and WHO published daily reports on the number of cases on its website. In parallel, reporting of epidemiological, clinical, and laboratory information occurred on a regular basis, mainly through the ground rounds (see discussion above on risk assessment mechanisms). These ground rounds were both a risk assessment and a risk management forum. New reports of information informed the risk assessment for reevaluation of the measures taken.

According to Greaves, (117 p. 288) a reporting system should be accurate enough to have a predictive value (a reported case should be a true case). It should be complete (with all or nearly all cases reported), timely (in that the reports are received by WHO in time for control measures to be effective), based on agreed case definitions, and electronic based. In practice, WHO's reporting system for SARS encountered problems in all these areas. The implementation of a reporting system facilitated the monitoring of the outbreak by providing epidemic trends and geographical maps, but the information was not fully reliable. It was a challenge for WHO to obtain accurate, complete, timely and case-definition-based information from the areas with local transmission of cases, as well as from areas encountering only imported cases, such as the United States. Some countries such as Thailand or Canada delayed the reporting of cases in order to avoid the impact on their tourism sector, but without major consequences for WHO analysis. Mistakes such as the reporting of cases that did not match the case definitions, as occurred in the United States, or that did not meet the laboratory requirements, as occurred in Taiwan, were subsequently corrected and final figures republished on the WHO website. While making our analysis of additional cases per day, we initially analyzed the data published under the *Cumulative Number of Reported Probable Cases of Severe Acute Respiratory Syndrome (SARS)* (104) on a daily basis and noted differences with the epidemic curves of affected areas that were published by WHO. We obtained negative values as a daily difference, which were corrected in the final epidemic curves for most of the affected countries, China being the most striking example. The completeness of the Chinese data was an issue, as indicated by the situation in Beijing. The WHO Beijing team estimated that Beijing might have as many as 200 cases of SARS, rather than the 37 officially reported cases, and requested improvement in the reporting and tracing system (118).

In addition, WHO needed SARS-related information to coordinate the global response, but had difficulty keeping up with the information flow. WHO was overwhelmed by the thousands of emails circulating in an uncoordinated way between country offices and headquarters, (36) and its website received up to ten million hits per day. The SARS task force was the central point of entry of information. The advantage was that it could centrally and consistently use the various internal sources of information (WHO mission reports, WHO regional and country offices communications, virtual networks sessions, teleconferences, phone conversations, email, etc.) to reassess the response to SARS. The disadvantage was that it failed to capture and manage every piece of relevant information in a timely and effective manner.

Although reporting was not perfect, countries generally participated in the reporting of cases. WHO launched the SARS reporting system on March 17, 2003, a few days after issuing the global alerts. Countries reported SARS cases in a standard format imposed by WHO on a daily basis, usually by email, and according to the case definitions provided by WHO. With the exception of China, which joined the network later, and the United States, which was reluctant to provide data to WHO, this reporting system was largely applied by areas with local chain of transmission. On March 24, 2003, 13 countries or regions (Canada, France, Germany, Hong Kong, Italy, Republic of Ireland, Singapore, Spain, Switzerland, Taiwan, United Kingdom, the United States, and Vietnam) reported the number of cases and deaths to WHO. China remained absent from the process until March 28, 2003, although Hong Kong and Taiwan reported their respective cases. The initial report format included the total number of cases, the number of deaths, and the local chain of transmission. On April 10, 2003, the number of new cases since the last WHO update and the number of cases who recovered were requested. On April 17, 2003, the last report was issued. This daily reporting constituted an important element of the evaluation of the evolution of the SARS outbreak in terms of local and international spread (presence of local chain transmission), severity of the disease (number of cases), and particular mortality (see discussion on case fatality ratio in the risk assessment mechanisms above).

2.2.3.2 Evaluating completion of measures

States generally complied with and applied WHO recommendations to contain SARS, sometimes after some delay, as in the case of China, or in an anticipatory manner, as in the cases of Vietnam, Singapore, and Hong Kong. Certain states, such as Singapore, even went beyond WHO recommendations, which were meant to set a minimal standard to respect. Anderson (72 p. 75) presented six categories of measures that can be undertaken to control a disease, which in fact correspond to the global recommendations issued by WHO, except for internal restrictions of population movements within a country. Table 2.6 summarizes the measures proposed by WHO and the measures applied by affected areas (except for the Philippines and Mongolia). The legal basis for action and the creation of a task force have been added to provide supplementary information, but are not part of the classification proposed by Anderson.

While social distancing measures were not prescribed by WHO, most affected areas applied them to control the disease. By doing so, they went beyond WHO recommendations. Isolation and quarantine were used with various degrees of coercion in different countries (e.g., surveillance of airline passengers' arrival in the United States, army surveillance in Singapore, a system of fines in Canada for failure to respect quarantine), but proved effective in reducing the mobility of the at-risk population, and therefore contributing to the containment of the disease. In addition, these affected areas set up a SARS-dedicated task force, which was not an explicit recommendation of WHO, but was contained as provision in the WHO influenza preparedness plan. Also, and not indicated in this table, it appeared that WHO recommendations in terms of case definitions and case management, and use of diagnostic tests, were largely followed by affected countries and other countries.

Field missions can contribute to the evaluation of the completion of measures, but the evaluation of completion remains voluntary. WHO lacks the authority to audit the activities of member states. WHO can neither review countries' measures for compliance with WHO's measures nor evaluate their effectiveness. WHO can act upon invitation or request for assistance from countries in order to provide support for disease containment (e.g., infection control, case management, etc.), but cannot act without the formal assent of the national authorities. In the case of SARS, WHO completed evaluation missions that drew conclusions about the adequacy of control measures taken in Guangdong, but not in Beijing. In Beijing, the underestimation of cases was reported even by health-care workers, contradicting the official position of the country. (58) However, these Chinese mission reports remained confidential and were not published. Because the evaluation of the completion of measures remains difficult, it has been proposed that the Communicable Diseases Department of WHO should include an operations and evaluation department to monitor the performance of member states and formally report their failures to adhere to established standards.

Table 2.6 WHO recommendations application by SARS affected countries

WHO	China	Hong Kong	Singapore	Vietnam	Canada	Taiwan
Legal Basis						
No formal basis at the time of outbreak; generally accepted practice based on IHR revision project WHA resolutions (May 2003) 2002 Revision Project IHR	New Regulation on Public (May 9, 2003) Health Emergency Response	Quarantine and Prevention of Disease Ordinance	Diseases Act	Missing information	Code Orange alert	Revised Public Health Code
Creation of a task force						
SARS task force	Ad hoc SARS committee on April 20, 2003	Working group on Severe Community-Acquired Pneumonia (CAP), then HWBR task force (international and local experts)	Ministerial and bureaucratic task force	SARS task force Ministry of Health	SARS Scientific Advisory Committee	Emergency task force
Restrictions on entry to the country and screening at the point of arrival for fever						
Screening recommended from departure of affected areas	Missing information	Temperature checks of travelers departing from HK.	Temperature checks of travelers departing from or arriving in Singapore.	SARS leaflets given to passengers departing from Vietnam	Screening of passengers departing from and arriving in Canada	Missing information

WHO	China	Hong Kong	Singapore	Vietnam	Canada	Taiwan
Isolation of suspect cases						
Global alerts (detection and isolation of cases based on case definitions)	Done in Guangdong and in other Provinces; problems in Beijing where one hospital is designated SARS hospital	Done and SARS-designated hospital	Done and SARS-designated hospital, Tan Tock Seng	Done and SARS-designated hospital (French Hospital in Hanoi)	Done and Grace Hospital designated as SARS hospital and closed	Done and Hoping Hospital designated as SARS hospital
Encouragement of rapid reporting to a health-care setting following the onset of defined clinical symptoms						
Global alerts, WHO publicly requires a reporting of cases to WHO	Done after April 20, 2003 (War on SARS becomes a top priority)	Done	Done, plus education campaign	Done	Done	Done, plus education campaign
Rigorous infection control measures in health-care settings						
Hospital Infection Control Guidance, Discharge policy, Clinical description	Done in Guangdong and other Provinces, problems in Beijing	Done, but infection of health-care workers could not be prevented	Done, but infection of health-care workers could not be prevented	Done, but infection of health-care workers could not be prevented	Done, but infection of health-care workers could not be prevented	Done, but infection of health-care workers could not be prevented
Restrictions on movements within a country (restricting travel, mass gathering, etc.)						
No social distancing measures prescribed. Issuance of travel restrictions for countries and regions.	People's surveillance measures (quarantine, schools closing, temperature checks, etc.)	Quarantine of Amoy Gardens residents; evacuation of Amoy Gardens	Mandatory home quarantine, school closing Temperature checks in schools, offices…	None	Quarantine, temperature checks	Mandatory home quarantine
Contact tracing and isolation of contacts						
Management of SARS (guidelines)	Done	Done	Done	Done	Done	Done

2.2.3.3 Incentive-based enforcement

The implementation of the response did not depend on enforcement provisions. There were no enforcement provisions to ensure the application of WHO recommendations for SARS. Under IHR, member states were not obliged to notify WHO of SARS outbreaks and report cases nor to apply the measures recommended by WHO. Until the World Health Assembly resolution that authorized the use of unofficial sources of information, WHO member states did not delegate specific competences for the enforcement of these measures, rendering their respect or their implementation not mandatory for national authorities. However, WHO measures received a large audience and were largely followed by member countries, the media, and the medical profession, as well as by individuals with access to the Internet worldwide. The structure of the response, which included innovative and cooperative mechanisms fostering commitment, combined with fear of the consequences of the publicly communicated information, constituted the major enforcement mechanism of WHO.

The structure of the response and the use of an incentive-based strategy ensured cooperation. WHO compensated for the lack of enforcement tools by the use of a confidence incentive-based system to obtain cooperation. WHO produced and disseminated verified information about the SARS epidemic that was mutually beneficial to all who could be perceived as having an incentive to cooperate. WHO would also communicate about problems obtaining cooperation, which would be relayed in the media, raising international awareness (and pressure) from other member states to gain the cooperation of the reluctant states. WHO also argued that rumors could be more damaging than facts in terms of loss of reputation and economic impact. (115 p. 9) The consequences could be a loss of credibility that affected diplomatic relations and trade. The fact that countries did not want to be openly pointed to as the "bad player" helped in most cases to ensure accurate and timely reporting of outbreaks and cases. Attempting to conceal an outbreak in the age of global and instant electronic communication, as China did in the case of SARS, has become impossible, and the political, economic, and reputational price of such behavior is high. (119 pp. 140–141) WHO used a range of channels of communication, such as letters to Chinese authorities, to request access, issue travel restrictions, and publicly assign blame pronounced by the WHO Director-General. (54 p. 101) It remained unclear what weight the international pressure from WHO and other countries exerted on China's decision to cooperate as compared to the danger presented by the worldwide evolution of the outbreak and scientific evidence of a new virus probably originating in Guangdong. But for WHO, it was certain that Chinese cooperation was key to containing the outbreak worldwide.

In addition, governments reluctant to provide information about an outbreak for fear of the economic consequences of being on the list of SARS-affected countries could be pressured to do so through the process of verifying information coming from unofficial sources. This incentive-based system was officially included in the World Health Assembly Resolutions of 2003, as well as in the revised IHR in 2005. WHO used information and communication as a strategy to leverage cooperation from states, as it does not have and does not want the power to use coercion. Dr. Rodier from WHO concluded that "WHO cannot be both physician and police force. If we are perceived as the policeman, doors will be closed.…Countries will comply because of a sense of global solidarity in the face of a common threat, but also they will comply because they prefer to maintain a good image and look responsible" (36).

Finally, the mandate of WHO is limited by the sovereignty of the country. WHO cannot decide to go into a country to proceed with on-site investigations unless it is invited to do so by that country. However, following the SARS outbreak in 2004, the idea was raised that the Security Council could intervene in such situations, although the modalities of such intervention have not been clearly set. If an outbreak of an overwhelming infectious disease cannot be verified and could represent an international security threat, the WHO Director-General can collaborate with the Security Council of the United Nations to establish effective quarantine measures. (120 p. 47 paragraph 144) The Security Council can support WHO in deploying investigators and experts, and in preparing to "mandate greater compliance." While it was clearly stated that the Security Council could assist in cordon operations, this mandate for greater compliance has not been clearly defined. In addition, to ensure compliance, certain authors propose that in cases of noncompliance, the United Nations Security Council be referred to the standards and absence of required corrective action. (121 p. 33) Such coercive action would contribute to the international securitization of public health issues and was not reflected in specific related rules of the revised IHR 2005.

2.3 Conclusion

WHO conducted a risk analysis that contributed to the reduction of the SARS pandemic risk. WHO organized multidisciplinary, internationally recognized, and geographically broad-based expertise to assess risk based on the latest scientific findings and the completion of innovative steering mechanisms relying on modern technologies. The quality of expertise and the innovative ways of organizing the experts in virtual networks significantly contributed to the risk analysis. WHO applied a risk analysis method, the legitimacy of which was action based rather than rule based given the nonapplicability of the IHR, while the cost analysis remained incomplete. WHO's response to SARS resulted in a decrease in casualties, was cooperation based, and was adequately monitored. The response resulted in the limitation of the international spread and the reduction of new cases, which led to the containment of the disease, and studies suggest that it was cost effective. In addition, the absence of consultation with countries before the issuance of travel restrictions reduced the level of cooperation, which remained otherwise significant. Finally, the reporting system provided useful information despite some problems with accuracy, completeness, and reliability. WHO recommendations were largely applied, despite the lack of enforcement provisions. The absence of coercive means of enforcement was compensated for by the structure of the response and the incentive-based system. These provided an alternative enforcement means that proved effective in helping rally China into the international partnership to fight the disease. Although cooperation and monitoring were impaired by minor deficiencies, on the whole they substantially improved the quality of the response. The quality of the relationship between risk analysis and the formation of an international appropriate response to SARS under WHO is illustrated in Figure 2.4.

The quality of risk analysis leaves some room for improvement. Risk analysis was impacted by the gap between WHO's need for global action and the competences that had been granted by member states, although WHO's direction was generally recognized and followed. Incomplete documentation of specific procedures regarding the management of health events, and the lack of experience with newly implemented structures such as GPHIN or GOARN, or with specially designed mechanisms such as the experts' collaborating networks and the ground rounds, may also explain some weaknesses in the process. The emergence of SARS was regarded as a real-life test of these structures and mechanisms. After the outbreak, WHO issued SARS-specific risk assessment guidelines to anticipate its possible resurgence and accelerated revisions of the IHR and the influenza preparedness plan in order to prepare for more significant outbreaks of infectious diseases. WHO rapidly coordinated a revision of the IHR in order to provide the organization and the countries with an adequate instrument for addressing outbreaks of infectious disease in a globalized world.

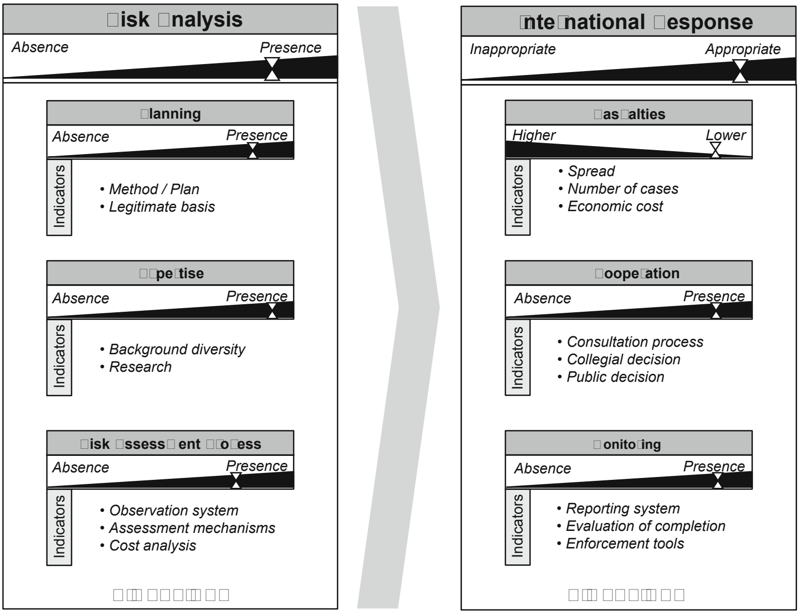


Figure 2.4 International response to SARS

Albeit challenged by the competition in a race to publish findings, WHO effectively led and coordinated collaborative scientific assessment of the risk of a SARS pandemic. It judged the risk of pandemic to be important and organized the international response in line with the results of its risk analysis. The initial high level of uncertainty about the disease led to the recommendation of control measures to ensure the maximum level of protection (i.e., early detection of cases, isolation, and barrier nursing), as well as the minimum disruption to travel and trade (the initial alerts did not include travel restrictions, but only indicated the affected areas). The establishment of virtual networks and the organization of ground rounds provided a platform of information sharing among virologists, epidemiologists, and clinicians in order to find the causative agent, establish the causal chain, evaluate the exposure and vulnerability of populations, and propose control measures to stop the spread of the disease. The virology network's results were instrumental in helping clinicians and epidemiologists more precisely tackle their research on transmission routes and case management, and more effectively plan their action in the field. Based on research progress, additional containment measures were adopted, such as quarantine or disinfection of sites when environmental contamination was suspected, in order to further limit the spread of the disease. Each time knowledge of the disease improved, recommendations and guidelines were updated.[49] New incoming information also fed the risk assessment process, which resulted in additional recommendations such as the travel restrictions issued based on evidence that symptomatic persons were continuing to travel and evidence of increases in the number of cases in certain locations. The duration of the outbreak was too short to allow the development of an adequate cure or vaccine, but that was the next step that was planned after the identification of the virus. Even when the outbreak showed signs of coming under control, WHO maintained its vigilance, since the ultimate objective was to contain SARS fully. WHO did not set a threshold of residual acceptable risk. It aimed at full containment, and this was reached on July 5, 2003.

The international response to the SARS pandemic risk remains an example of an appropriate international response: it reduced the global risk of SARS, was based on an unprecedented level of international cooperation, and was adequately monitored. The international response was mainly organized around containment strategies generated by the risk assessment and which included case and contact management, infection control in hospitals and other facilities, community-wide temperature screening, use of masks, isolation, and quarantine, and the monitoring of travelers and response at national borders. (122 p. 75) Interview-based screening at airports to detect symptoms was also conducted in affected most areas (although not the taking of passengers' temperatures, which was not explicitly indicated in WHO's recommendations). The implementation of infection control measures within hospital settings was particularly challenging, and required education campaigns. Health-care staff had to be reminded and specifically trained to deal with SARS in accordance with its epidemiological and clinical characteristics.

Although risk analysis under WHO proved to be a determining factor in the formulation of an appropriate international response in the SARS outbreak, other factors also contributed to the containment of SARS, which is often referred to as a global public health success. First, political commitment supported the international response. In particular, Association of Southeast Asian Nations (ASEAN) countries met during the SARS crisis to agree upon intervention measures, which contributed to the achievement of the regional response. Also, China's eventual political commitment to fighting SARS was comparable in determination to its initial concealment and denial, showing how transparent reporting and communication, as well as international cooperation, can help contain a disease worldwide. Second, the availability of information and communication technologies, in particular electronic networking, allowed real-time performance of SARS risk analysis and the sharing of findings among scientists all over the world. This interconnectedness also benefited control efforts by allowing rapid and global dissemination of information and recommendations. (67 p. xxiii) Third, speed and leadership were key to ensuring control of an infectious disease such as SARS. At the global level, speed and leadership were ensured by WHO, with a new disease contained worldwide in a few months. At the national level, governments had enough power, willingness, and public health resources to participate in the international risk analysis and enact the containment measures. The initial delay in obtaining information about China and access to its territory could have been critical if the disease had been more infectious and measures to contain it had been taken less seriously by national authorities in Asia, Europe, and America. Finally, by fortune, virus characteristics such as its reproduction rate contributed to the containment of SARS.

The achievement of SARS containment revealed WHO's central role in the assessment and management of public health emergencies of international scope. WHO's leading role in the risk assessment and risk management of the SARS crisis was validated by the World Health Assembly in May 2003 by the approval of a SARS-specific resolution backed by a resolution on the IHR revision, solving the rules-based legitimacy issue of WHO in the face of SARS. This resolution increased the global role of WHO by requesting increased action regarding the update and dissemination of WHO guidelines, the strengthening of the activities of the Global Alert and Response team and of the collaborative networks, and development of the research and country assistance programs. One important novel point of the IHR resolution is the agreement about a more global active role for WHO in outbreak detection and verification, issuance of alerts, risk assessment, and evaluation of the adequacy of control measures. This resolution was influenced by the problems with communication, reporting, and access encountered with China during the SARS outbreak, but it also confirmed WHO's position as a leading actor in the assessment and management of infectious disease outbreaks at a global level.