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Expert judgments of pandemic influenza risks

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Abstract

Structured surveys were conducted with 19 medical experts, and 17 non-medical experts in related fields, attending a meeting about pandemic influenza. Respondents gave quantitative judgments for key variables potentially affecting the extent of a possible H5N1 pandemic. The medical experts saw about a 15% (median) chance of efficient human-to-human transmission, in the next 3 years. Should it occur, they saw almost no chance of there being adequate vaccines or antiviral responses. They saw varying chances of six other mitigation strategies reducing the threat, expressing the greatest faith in improved surveillance. Compared to the medical experts, the non-medical experts saw much higher chances of both human-to-human transmission and of effective vaccine and antiviral responses being available. The medical experts and the non-medical experts had similar, dire predictions for the extent of casualties, should transmission occur in the next 3 years. Their responses to open-ended questions revealed some of the theories underlying these beliefs.

Keywords: *Pandemic influenza, risk, expert judgment, preparedness, non-pharmacological interventions*

Introduction

Given the spread of H5N1 among birds (Sims et al. 2005), public health officials need to make difficult choices about allocating scarce resources among measures with uncertain effectiveness (World Health Organization Writing Group, 2006a, 2006b). They also need to provide guidance, to everyone else in society, regarding

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the nature of the threat, in clear enough terms to allow people to make the best possible plans, under the circumstances.

Advances in medical science have provided unparalleled forewarning regarding the threat of pandemic influenza and the opportunities for reducing it. Nonetheless, predicting the course of the potentially looming pandemic is a highly uncertain enterprise. It involves the interaction of complex physiological and social processes, many of which are poorly understood in isolation, much less in these unique circumstances. Inevitably, those predictions are an exercise of judgment, the expertise for which is distributed over many individuals and disciplines. This article presents one product of a project designed to elicit such judgments in a disciplined, transparent way.

Our approach is straightforward. We created a conceptual model of the processes affecting the course of a pandemic arising from avian influenza, should it evolve to a state where efficient human-to-human transmission occurs (Fischhoff 2006). The model identifies processes predicting the potential consequences of pandemic influenza, such as morbidity and mortality, health care costs, and economic costs (due, for example, to decreased business activities and societal disruption). It also considers how potential interventions (e.g. improved surveillance, social distancing) would affect those processes. The model is defined in terms of variables and relationships, such that the consequences could be predicted, were its data requirements satisfied. It uses the formalisms of influence diagrams (Clemens 1997, Fischhoff 2000), which allow accommodating diverse forms of knowledge, including observation, judgment, and theory. We have developed similar models, at varying levels of detail, for predicting risks of sexually transmitted infections (Fischhoff et al. 1998), cryptosporidium in drinking water (Casman et al. 2000), breast implants (Byram et al. 2001), and climate change (Casman et al. 2001), among other things (Morgan et al. 2001). Like all modeling, their creation is an exercise in judgment, involving iterative review by experts.

Having identified relevant issues through this process, we elicited quantitative estimates for some of the model's critical parameters, along with qualitative explanations of the supporting theories, following established procedures for such elicitation (von Winterfeldt and Edwards 1986, Fischhoff 1989, Morgan and Henrion 1990, Morgan and Keith 1995). Respondents received the questions in a written survey, as part of their preparation for a gathering of experts, in early November 2005. Initial data analyses were discussed at the meeting, providing additional context for the interpretations offered below. Although these judgments will become dated, as the situation changes and scientific knowledge grows, they provide a picture that is not otherwise available and that can be retaken over time, providing policy makers with the assessments that they need for planning.

Method

Participants

The survey was emailed to the 49 individuals invited to the Pandefense 1.0 November 2005 meeting, which focused on reducing the probability and effects of a pandemic. Thirty-six returned the survey, four of whom were, subsequently, unable to attend. Participants were senior scientists and administrators from medicine and other fields relevant to pandemic risks. Almost all were currently based in North America, although many had international experience. Nineteen were medical experts, with specialties related to epidemiology and influenza. The remaining 17 non-medical experts defined their areas as sociology or political science (6), business (6), disaster-relief non-profits (4), and politics (1). The terms of the invitation precluded revealing names of any participants (other than the organizers). Carnegie Mellon University's Institutional Review Board approved this reporting of the survey data.

Procedure

Respondents received the survey by e-mail, 3 weeks before the meeting. Its rationale was explained as: 'Your answers will help us focus the meeting on the most relevant issues, as well as to provide everyone with a snapshot of the range of opinions in the room'. Participants were ensured that 'the results will be confidential. We will not store your answers with your name. We will only report aggregate data and will never report your answers with your name. (However, you will have plenty of time to make your views known during the meeting.)'

Probability judgments were elicited with a rating scale that offered the response options: 0%, <1%, 10%, 20%, ... 100%. Offering the <1% option followed Woloshin et al. (2000), and allowed respondents to express non-zero probabilities for very unlikely events. Questions were phrased so that near-0% values were plausible, while near-100% values were not, accounting for the scale's asymmetry. Respondents were also offered the option of 'no idea what answer to give', in order to allow those who felt no expertise to opt out.

The scale was introduced with: 'Most of the questions in this survey ask you to place an X on a probability scale that goes from 0%, meaning that you think it is certain not to happen, to 100%, meaning you think it is certain to happen. The response option "<1%" is for probabilities between 0 and 1%. If you have no idea what answer to give, please place an X next to "No idea what answer to give". (At the end of the survey, we have added references about this kind of probability elicitation).' Those references are marked with an asterisk (*) in the reference section of this paper.

We sought to formulate the events, whose probability was being judged, precisely enough that they (a) would be interpreted similarly by all respondents and (b) could be evaluated in the light of subsequent experience. In some cases, full specification would have taxed respondents' information processing capability. As a result, there is some chance that they 'read between the lines' differently, when inferring missing details (Fischhoff 1994). We provided the details that seemed most important and hoped that common perspectives were shared within this professional community. Nonetheless, response variance may reflect how respondents interpreted a question as well as what they believed about it.

Questions

We now present the questions, in their order of appearance, reflecting the narrative flow of the questionnaire. They are organized more topically in the data analyses that follow.

Pandemic influenza risk. The survey began with the question, 'What is the probability that H5N1 or a similar virus will become an efficient human-to-human transmitter (capable of being propagated through at least two epidemiological generations of affected humans) sometime during the next 3 years?'

Availability of vaccines and antivirals. The next two questions asked, 'If H5N1 or a similar virus becomes an efficient human-to-human transmitter in the next 3 years, how likely is it that there will be sufficient quantities of an effective human vaccine to vaccinate one-third of the world population at that time?' and, given the same assumption, 'How likely is it that there will be sufficient quantities of an effective antiviral pharmaceutical to treat one-third of the world population at that time?' followed by the explanation 'by "an effective antiviral pharmaceutical" we mean that, among influenza patients treated with the drug in a timely manner, 75% show no further progression of symptoms, and 75% no longer spread the disease'.

Case-fatality rate. Subsequent questions were conditioned on the assumption that H5N1 or a similar virus becomes an efficient human-to-human transmitter in the next 3 years, while there are still insufficient quantities of either effective antiviral pharmaceuticals or an effective vaccine (including perhaps none at all) at that time. Under those assumptions, respondents first filled in a blank estimating 'the most likely case-fatality-rate worldwide', allowing them to give more specific numbers than available on the scale used with the other questions.

Mitigation strategies. This section sought a balance between eliciting standard responses and allowing respondents to focus on topics of personal interest. It began by asking them to 'list at least three mitigation strategies (actions that individuals, governments or other agencies can take to reduce morbidity and mortality) that you believe will be most effective for reducing the severity of an outbreak of H5N1 or a similar virus in the USA'. It, too, asked respondents to assume the absence of effective pharmaceutical interventions.

For each of these mitigation strategies, we asked, 'How likely it is that [the strategy] will reduce the severity of an outbreak of H5N1 or a similar virus among humans in the USA', using the probability scale, and to 'list the most important factors affecting how effective this strategy will be and whether it can be used at all'. Note that 'reduce the severity' is a verbal quantifier, which could be interpreted in various ways (e.g. enough of a reduction to be detected, enough to make a meaningful difference, enough to solve the problem). Assuming that each respondent interprets the term the same way for each question, their responses should capture their beliefs regarding the relative likelihood of strategies reducing the severity, even if ambiguity remains regarding what 'reduce' means in absolute terms. Next, participants were asked to list 'any mitigation strategies that you believe are just not worth trying for reducing the severity of an H5N1 outbreak in the USA' and to explain 'why it is not worth trying'.

Participants were then asked to judge and explain the probability of severity reduction for six mitigation strategies: (a) 'a mass vaccination programme with currently available "regular" influenza vaccine for all poultry workers and other people exposed to birds and fowl'; (b) 'effective antiviral pharmaceuticals to several hundred thousand people living in a ring around the first-detected cases of human-to-human H5N1 (as suggested by "epidemiological modelers such as Ira Longini")'; (c) 'an improved influenza surveillance system, which increases our ability to detect and report human cases of H5N1 or other highly pathogenic viruses'; (d) 'an aggressive campaign of "social distancing" measures, such as quarantine, isolation, goods embargo, home schooling, and travel restrictions'; (e) 'an aggressive campaign of barrier methods, such as masks, goggles, gloves, and hand washing'; and (f) 'an aggressive campaign of animal control measures, like vaccinating, treating, culling, and segregating birds and livestock'.

Terminology. Participants were asked how clear they thought that the terms 'social distancing' and 'bird flu' would be to the general public, with response options being 'very clear', 'somewhat clear', and 'not clear'. They were also asked to suggest alternative terms.

Number of mutations. The next question said that 'there are many ways in which H5N1 or a similar virus can mutate from the situation today (in which the virus is spread bird-to-bird or bird-to-pig with the occasional bird-to-human transmission) into a situation in which the virus becomes an effective human-to-human transmitter', then asked, 'in the next 3 years, how many such mutations do you think there will be'? Response options were 'none', '1', 'between 1 and 5', 'more than 5', and 'no idea'.

Availability of antivirals. The next question asked for best-case and worst-case answers to the question, 'if there is an outbreak of H5N1 or a similar virus among humans in the next 3 years, how many full courses of effective antiviral pharmaceuticals (i.e. enough medicine to protect one person for one exposure cycle) do you think we will have in the USA at the time?'

Number of people affected. The next set of questions asked for best-case and worst-case estimates of the number of people that would be affected by an H5N1 outbreak in the next 3 years, assuming the lack of sufficient antivirals and vaccines. Separate questions were asked about people sick and people dying, for the USA and the world. Estimates of sick and dying worldwide should be consistent with the estimated case-fatality rate worldwide. Thus, a comparison of these responses provides a check on the coherence of respondents' beliefs.

Consequences. The next question asked respondents to list the most important consequences of a worst-case outbreak, in addition to human morbidity and mortality.

Timing. The final task asked respondents, 'when do you think that effective human-to-human transmission of H5N1 or a similar virus (affecting at least two epidemiological generations) will occur?' followed by 'I think that there is a 10% chance of it occurring within the next . . . year(s)' and similar questions for 50%, 90%, and 100%. Respondents were instructed that 'You can use fractions, if you think that it will take less than a year. You can fill in "never" if you think that it will never happen'. These questions address the same issue as the first one, which asked respondents to judge the probability of a pandemic influenza occurring in the next 3 years. Thus, a comparison of these responses provides a check for the coherence of these beliefs.

Results

Pandemic influenza risk

Figure 1a shows the response distribution for the survey's first task, assessing the probability of H5N1 or a similar virus becoming an efficient human-to-human transmitter in the next 3 years. No respondent said 0%. Medical experts gave significantly lower median probabilities than did non-medical experts (mdn = 15% vs. mdn = 60%, Mann-Whitney U $z = 2.46$, $p < .05$). Medical experts were less likely than non-medical experts to select 'no idea' or leave the item blank (5% vs. 29%), $t(34) = 1.99$, $p < .10$.

Timing

When respondents were asked to match years to probabilities (the survey's final task), their median estimate of the number of years until there would be a 10% chance of pandemic influenza was 1.5. For 50%, 90%, and 100% chances, the median estimates were 3.5, 15, and 30 years, respectively. Medical experts gave significantly longer estimates than did non-medical experts for the time period

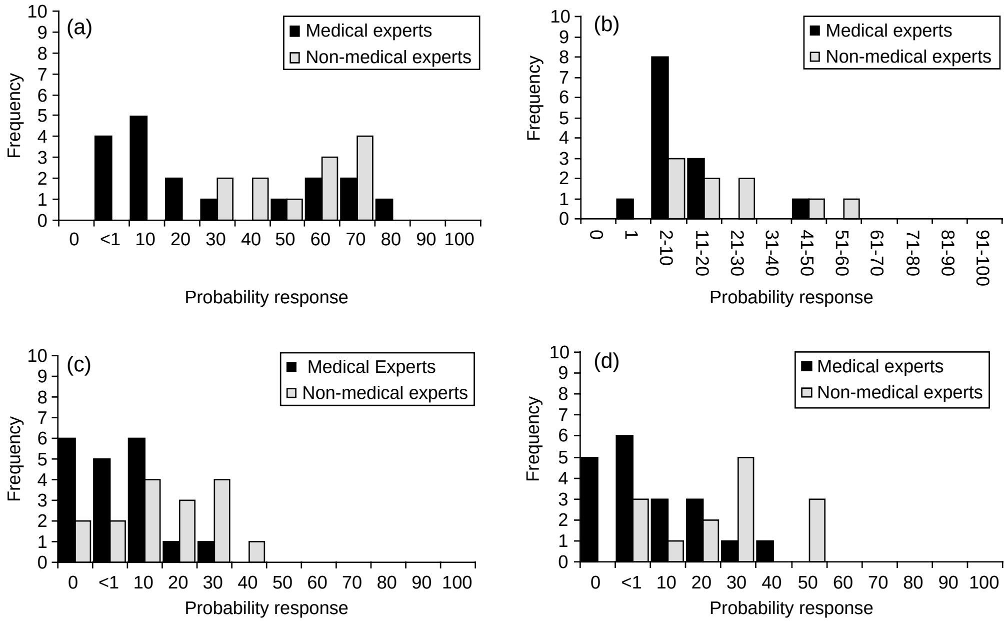

Figure 1. Response distributions for the probability that (a) H5N1 or a similar virus will become an efficient human-to-human transmitter in the next 3 years, (b) someone who is infected will die, or the case-fatality rate, (c) we will not have sufficient quantities of effective vaccines at that time, and (d) we will not have sufficient quantities of effective antiviral pharmaceuticals at that time. Figure (b) presents categories of open-ended responses, whereas the other figures present responses on the probability scale described in the text.

that it would take to reach a 10% chance of a pandemic (3 years vs. 1 year; Mann-Whitney U $z = 2.52$, $p < .05$) and a 50% chance (10 years vs. 3 years; Mann-Whitney U $z = 2.69$, $p < .01$), but not for a 90% or a 100% chance. Non-medical experts were more likely than medical experts to say that it would 'never' reach a 90% chance or to give no response to that question (65% vs. 32%; $\chi^2(2) = 3.95$, $p < .05$); similarly, for a 100% chance (76% vs. 32%; $\chi^2(2) = 7.26$, $p < .01$). Figure 2 shows cumulative response curves. For both groups, the curves imply probabilities of approximately 10% for transmission occurring within 3 years. That estimate is roughly consistent with the direct estimates (see Figure 1a) of the medical experts, but not those of the non-medical experts, suggesting greater coherence in the medical experts' beliefs.

Number of mutations

Ninety-four percent of respondents estimated the number of mutations of H5N1 into an effective human-to-human transmitter (rather than saying 'no idea' or leaving the item blank). Among them, 25% expected 'between 1 and 5' of such mutations, while the rest expected 'more than 5'. Medical experts and non-medical experts responded similarly.

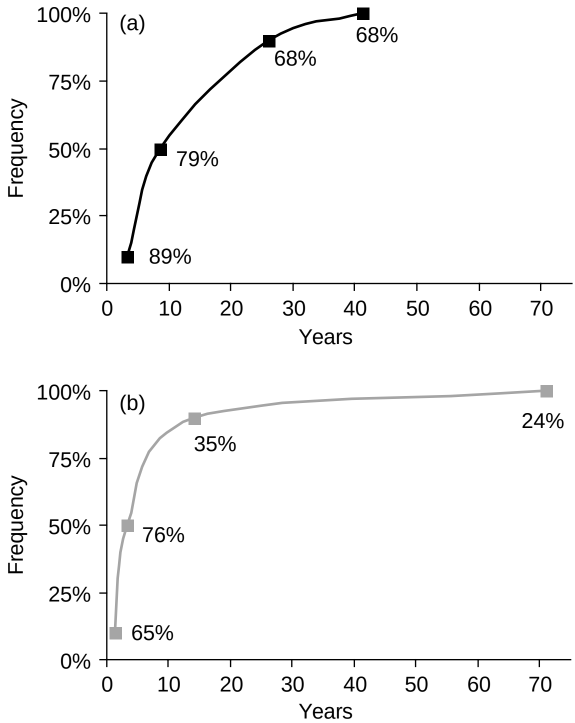

Figure 2. Estimates for the timing of an outbreak of H5N1 or a similar virus among humans, given by (a) medical experts and (b) non-medical experts. The number by each point indicates the percentage of respondents who gave an estimate for the number of years that it would take to reach that level of probability (10%, 50%, 90%, and 100% probability, respectively).

Case-fatality rate

Thirty-nine percent of respondents answered 'no idea' or gave no response when asked about the most likely case-fatality rate, indicating how challenging they found this question. The non-response rate was similar in both groups. Among the remaining respondents, the median estimated case-fatality rate was 7% for medical experts and 20% for non-medical experts (Mann-Whitney U $z = 2.93$, $p < .05$). Figure 1b presents the distributions of these open-ended responses, grouped by category.

Number of people affected

Assuming that antivirals and vaccines would not be available, the best-case and worst-case estimates for the USA across medical experts and non-medical experts were 15,000,000 and 100,000,000 for people sick, and 500,000 and 6,000,000 for people dead. For the world, the comparable medians were 450,000,000 and 2,000,000,000 for people sick, and 20,000,000 and 180,000,000 for people dead. Responses were missing for 28% of the best-case USA estimates, 25% of the worst-case USA estimates, and 33% of the world estimates. Medical experts and non-medical experts answered similarly.

A sign test indicated that respondents' estimates for world-wide case-fatality rate were significantly higher than the case-fatality rates implied by their worst-case estimates for the world, produced by dividing their estimates of sick and dead ($p < .000$), but not significantly different from their implied best-case estimates. These responses reveal generally consistent beliefs, despite the observed disagreements and non-response rates.

Availability of vaccines and antivirals

All of the medical experts provided probabilities for sufficient quantities of effective vaccine and for sufficient quantities of effective antivirals being available. Six percent of non-medical experts had 'no idea' for the vaccine question and 18% for the antivirals question.

Respondents who answered the questions assigned a median 10% chance to having sufficient quantities of an efficient vaccine (see Figure 1c) or of efficient antiviral pharmaceuticals (see Figure 1d), in the 3-year period. Medical experts gave lower probabilities than did non-medical experts for both vaccines (mdn = " <1%" vs. mdn = 15%, Mann-Whitney U $z = 2.46$, $p < .05$) and antivirals (mdn = <1% vs. mdn = 30%, Mann-Whitney U $z = 2.93$, $p < .01$).

The median best-case and worst-case estimates for available courses of effective antivirals in the USA were 62,500,000 and 10,000,000, with no significant difference between medical and non-medical experts. Their non-response rates were similar as well (17% for best case, 19% for worst case.).

Mitigation strategies

Respondents volunteered 25 different mitigation strategies worth trying in the absence of sufficient doses of effective pharmacological interventions (see Table I). We identified five categories of suggested strategy: social distancing, public education, medical care, surveillance, and animal control. Medical experts and non-medical experts were equally likely to mention at least one strategy falling into each category. Strategies *not* worth trying could be classified into the same five categories, with medical experts and non-medical experts covering the categories similarly. Several strategies were cited as both worth trying and not worth trying, by different individuals, including social distancing (i.e. quarantine, travel restrictions, screening of travellers) and animal control measures (i.e. culling).

At least one variant of each of these five strategy categories was evoked by the six mitigation questions that all respondents considered. 'No idea' or no response was given by 28% of respondents for the question about vaccinating poultry workers, by 17% for ring antivirals and for surveillance, by 22% for social distancing, by 25% for barrier methods, and by 33% for animal control, with no significant differences in these rates for medical experts and non-medical experts.

Table I. Mitigation strategies worth trying and not worth trying, and percentage of respondents who mentioned each.

Worth trying	Not worth trying
Social distancing	
Isolation/quarantine of the infected (36.1%)	Military or large-scale quarantine (27.8%)
Travel restrictions (19.4%)	Quarantine of specific groups (2.8%)
Work and study from home (13.9%)	Closing borders/areas (2.8%)
Close schools or public gatherings (11.1%)	Screening at borders (2.8%)
Adopt non-contact greetings (8.3%)	Survivalist strategy (2.8%)
Screening at airports (5.6%)	Travel restrictions (2.8%)
Public education and outreach	
Increase general awareness (36.1%)	Fear-based communications (5.6%)
About personal hygiene (33.3%)	
About barrier methods (33.3%)	
About what to stockpile (11.1%)	
About food safety (2.8%)	
Medical care	
Strategic use of antivirals/vaccine (30.6%)	Large-scale antiviral prophylaxis (2.8%)
Antibiotics and other treatments preventing secondary infections (8.3%)	Vaccines (2.8%)
Treatment with statins (5.6%)	
Train neighbourhood medical teams (5.6%)	
Train survivors to give care (2.8%)	
Surveillance	
Faster/increased surveillance (19.4%)	
Better communication system (11.1%)	
Develop self-assessment assay (5.6%)	
Third world surveillance (2.8%)	
Animal control	
Ban outdoor housing/markets (5.6%)	Culling wild birds (2.8%)
Vaccination (5.6%)	Quarantine imported birds (2.8%)
Limit contact with humans (2.8%)	
Surveillance (2.8%)	
Culling (2.8%)	

Figure 3a–f shows response distributions for judgments of the probability that each strategy would ‘reduce the severity’ of an influenza outbreak. The medians were 20% for mass vaccination of poultry workers, 30% for ring antivirals, 55% for improved influenza surveillance, 30% for an aggressive campaign of barrier methods, 40% for social distancing, and 27% for animal control. There were no significant differences between medical experts and non-medical experts for any of these judgments (all $p > .05$). Kendall’s coefficient of concordance indicated significant agreement, across respondents, regarding the relative effectiveness of these strategies, as implied by their judgments of the probabilities of outbreak reduction (Kendall’s $W = .26$, $p < .01$).

Table II presents the factors listed as affecting the effectiveness of these strategies.

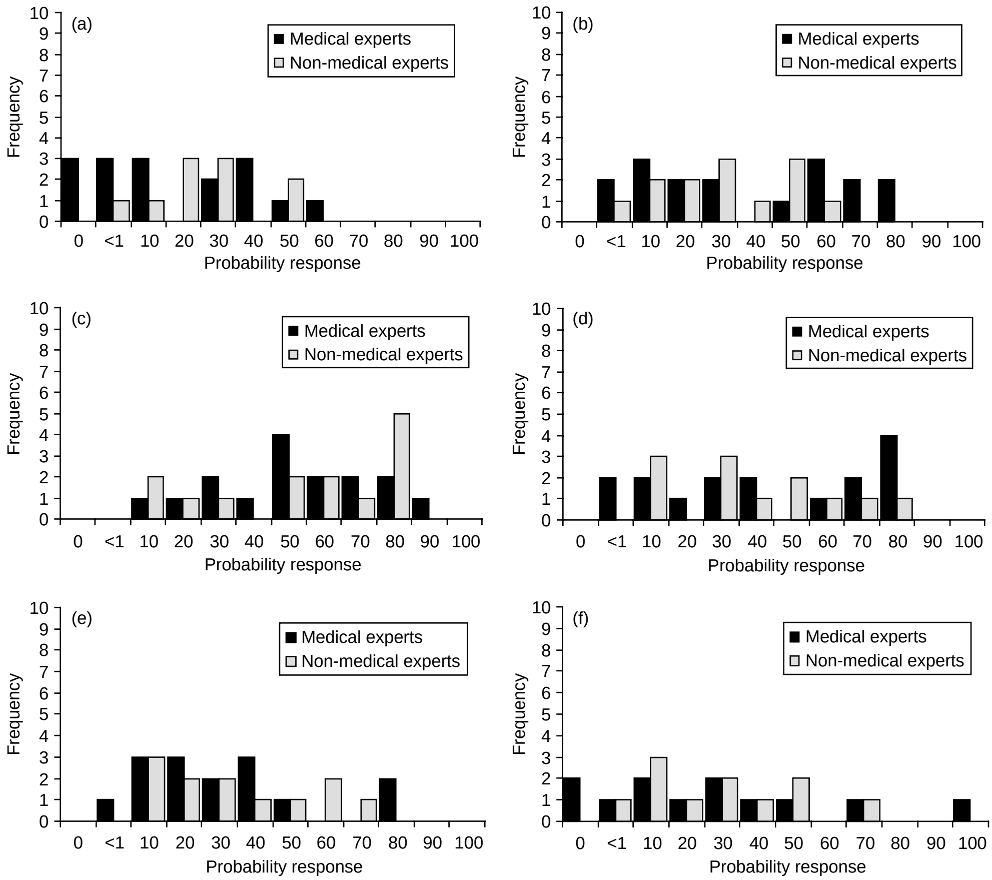

Figure 3. Response distributions for the probability that each of six mitigation strategies will reduce the severity of an outbreak: (a) a mass vaccination programme with currently available 'regular' influenza vaccine for all poultry workers and other people exposed to birds and fowl; (b) effective antiviral pharmaceuticals to several hundred thousand people living in a ring around the first-detected cases of human-to-human H5N1 (as suggested by 'epidemiological modellers such as Ira Longini'); (c) an improved influenza surveillance system, which increases our ability to detect and report human cases of H5N1 or other highly pathogenic viruses; (d) an aggressive campaign of 'social distancing' measures, such as quarantine, isolation, goods embargo, home schooling, and travel restrictions; (e) an aggressive campaign of barrier methods, such as masks, goggles, gloves, and hand washing; (f) an aggressive campaign of animal control measures, like vaccinating, treating, culling, and segregating birds and livestock.

Terminology

Among the 94% of respondents who answered this question, 74% believed that the term 'social distancing' would be 'unclear' to the public, with 6% saying 'somewhat clear' and 21% 'very clear'. The two groups responded similarly. Suggested alternative terms included quarantine, personal space, minimal social contact, voluntary isolation, self-isolation, self-sufficiency, infection-avoidance behaviour, disease containment, and good hygiene.

Table II. Important factors affecting the effectiveness of different strategies, and percentage of respondents who mentioned each.

Vaccinating poultry workers

Vaccines
- Availability (13.9%)
- May not stop reassortment (13.9%)
- Effectiveness for human flu (11.1%)
- Safety (5.6%)

Implementation
- Finding those who qualify (22.2%)
- Compliance (13.9%)
- Strict enforcement (8.3%)
- Missing other risk groups (8.3%)
- Political will (5.6%)
- Speed of implementation (2.8%)
- Need repeat vaccinations (2.8%)

Outbreak Specific
- Useless if human-to-human (16.7%)

Ring antivirals

Antivirals
- Availability (13.9%)
- Effectiveness (8.3%)
- Build resistance (11.1%)
- Toxicity (2.8%)

Implementation
- Effective quarantine (33.3%)
- Early detection (25.0%)
- Effective surveillance (22.2%)
- Rapid distribution (22.2%)
- Political will (13.9%)
- Funding (8.3%)
- Compliance (5.6%)

Outbreak Specific
- Number of outbreaks (16.7%)
- Ease of spread (19.4%)
- Location (11.1%)

Barrier methods

Barriers
- Effectiveness (11.1%)
- Availability (19.4%)
- Correct size and fit (2.8%)
- Chlorine-saturated (2.8%)

Implementation
- Compliance (38.9%)
- Correct application (13.9%)
- Effective lines of authority (8.6%)

Education
- Clear messages (19.4%)

Outbreak specific
- Ease of spread (11.1%)
- Mode of spread (8.3%)
- Stage of outbreak (2.8%)
- Population density (2.8%)

Surveillance

Test
- Accuracy (13.9%)
- Availability (5.6%)
- Invasiveness (5.6%)

Implementation
- Widespread (25.0%)
- Early detection (19.4%)
- Political will (16.7%)
- Funding (16.7%)
- Efficiency of reporting (13.9%)
- Multiple detection strategies (5.6%)

Outbreak Specific
- Asymptomatic cases (13.9%)
- Location(s) (11.1%)
- Timing (5.6%)

Social distancing

Implementation
- Compliance (19.4%)
- Strict (military) enforcement (13.9%)
- Hard to maintain over time (13.9%)
- Negative effect on society (11.1%)
- Speed of implementation (8.3%)
- Effective lines of authority (8.3%)
- Effective intelligence (5.6%)
- Funding (5.6%)
- Political backlash (5.6%)

Information
- Clear messages (22.2%)
- Retain trust (13.9%)

Outbreak Specific
- Timing (5.6%)
- Location (2.8%)
- Population density (2.8%)

Animal Control Measures

Implementation
- Universal enforcement (30.6%)
- Political will (8.3%)
- Effectiveness (2.8%)
- Wild birds uncontrollable (13.9%)
- Surveillance (5.6%)
- Compliance (5.6%)
- Finding exact location (5.6%)
- Funding (2.8%)

Outbreak Specific
- Useless if human to human (16.7%)

Of the 97% who evaluated the term ‘bird flu’, 29% believed it would be ‘unclear’, 20% ‘somewhat clear’, and 29% ‘very clear’. Again, the two groups responded similarly. Suggested alternative terms included avian flu, H5N1 influenza, pandemic influenza, the 1918 flu, human bird flu, super bird flu, and mutating flu.

Consequences

Table III lists anticipated consequences of a worst-case outbreak, other than morbidity and mortality, organized by possible implicit categories. These effects included business activities, social resilience, political unrest, medical care, shortages, and demographics. Members of the two groups were as likely to mention each category and specific consequence.

Discussion

The 19 medical experts in our sample saw a 15% (median) chance of efficient human-to-human transmissions of H5NI or a similar virus in the next 3 years. On a formally comparable question, using a different format, they estimated that 3 years would have to pass before the chance was 10%, indicating some coherence to their belief in a low, but non-negligible risk. Should transmission happen, most medical experts expected it to occur through more than five independent mutations, which could substantially complicate containment of the virus (Mills et al. 2006). Furthermore, the medical experts’ median expected a case-fatality rate (worldwide) was 7%, generally consistent with their estimates for the numbers of people sick and dying. The medical experts saw a tiny chance ($<1\%$) of there being adequate vaccine or antiviral solutions for the USA, if efficient human-to-human transmission were to occur in the next 3 years. Their best- and worst-case estimates of antiviral availability were 62.5 and 10 million courses.

Table III. Most important consequences of a worst-case outbreak, other than morbidity and mortality.

Business activities	**Shortages**
Economic disruption (80.6%)	Food (13.9%)
Effects on transport industry (13.9%)	Goods in general
Effects on communications (5.6%)	Effect on the poor (5.6%)
Effects on poultry industry (5.6%)	Oil/gas (2.8%)
Effects on financial markets (5.6%)	
Social resilience	**Demographics**
Political instability (38.9%)	Long-term effects (5.6%)
Societal disruption (38.9%)	Migration (2.8%)
War and terror (27.8%)	Loss of young people (2.8%)
Mental health effects (19.4%)	Orphans (2.8%)
Social fabric disruption (13.9%)	**Other**
Public panic (13.9%)	Ongoing viral mutation (2.8%)
Loss of trust in government (11.1%)	Unprepared for disasters (2.8%)
Isolation of the poor (2.8%)	

Given these beliefs, it is not surprising that the medical experts saw dire prospects, should efficient transmission occur. For the USA, their best- and worst-case estimates were 15 and 100 million people sick, and 0.5 and 6 million dead. For the world, the corresponding estimates were 450 and 2,000 million sick, and 20 and 180 million dead. For comparison, 65,681 people were reported as having died from pneumonia and influenza in the USA in 2002 (Anderson and Smith 2005).

The medical experts proposed many possible mitigation strategies (see Table I) and factors to consider in their implementation (see Table II). Among the six strategies that all respondents evaluated, the most likely to 'reduce the severity' of an influenza outbreak was improved influenza surveillance, followed by social distancing, barrier methods, ring antivirals, animal control, and mass vaccination of poultry workers. Although we cannot tell how large a reduction each of our respondents had in mind, their judgments of the relative effectiveness of strategies can be interpreted. Respondents ranked the six strategies in a similar order.

Compared to these medical experts, the 17 non-medical experts saw significantly greater chances of efficient transmission (60% vs. 15%) within 3 years and a shorter period before reaching a 10% of it happening (1 year vs. 3 years). The non-medical experts' best guess at the case-fatality rate was also significantly higher (20% vs. 7%). On the other hand, they were much more optimistic about the probability of adequate availability for vaccines (15% vs. <1%) and antivirals (30% vs. <1%). On other questions, the medical experts and non-medical experts produced similar judgments. They saw equal probabilities of the six mitigation strategies reducing the severity of an outbreak. In terms of expected sick and dead people, in the USA and the world, the non-medical experts provided best- and worst-case estimates similar to those of the medical experts. Possibly, the greater optimism of the non-medical experts regarding pharmacological solutions balanced out their greater pessimism about the speed of efficient human-to-human transmission.

Generally speaking, the medical experts and non-medical experts tended to agree on issues involving the interaction of physiological and social processes (e.g. the efficacy of interventions), where they had complementary forms of expertise. They tended to disagree about medical issues, where the medical experts should be better informed.

Responses to the open-ended questions reveal the thinking underlying these estimates. Some reflect factors that respondents believe should be included or excluded from a comprehensive risk model. (A few, such as social distancing, appear in both roles, for different respondents.) Others provide details to consider when elaborating plans for managing a pandemic or a model for predicting its course. The heterogeneity of these concerns is commensurate with the complexity of the issues, and with the disagreement seen in many of the response distributions. The degree of consensus is as relevant to decision-making as is the central tendency of these distributions: policy makers need to know how predictable an event is. Thus, it is important to know that the median 7% case-fatality rate was endorsed by almost all medical experts (see Figure 1b), while the median 15% probability of efficient transmission obscures a minority of medical experts who saw a much greater chance (see Figure 1a).

As mentioned, these judgments reflect the opinions of one group of specialists, whose identity cannot be revealed because of the confidentiality promised with the survey and the meeting. They represent opinions in mid-October 2005, on a topic where the science and the reality are changing. Some of the questions are less fully specified than would be possible with the one-on-one interviews of a formal risk analysis. Nonetheless, they show the kinds of explicit judgments needed to translate experts' rich knowledge into policy-relevant terms. Some of the gaps between the judgments of the two groups regarding the more medical issues may have reflected difficulties that the non-medical experts experienced when trying to discern the experts' beliefs from other venues (scientific articles, media reports, conference conversations) suggesting a need for eliciting expert judgment and communicating it to a broader audience. Of course, there is no real substitute for solid, theory-based empirical data. However, in its absence, expert judgment should be elicited in an explicit systematic way, so that policy makers know just what individual experts believe and how much agreement there is among them.

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[Note: Those marked with an asterisk (*) appeared in the 'References on probability elicitation' at the end of the survey.]

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