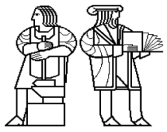

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PLANNING FOR A FLU PANDEMIC: POLICIES TO EMPOWER INDIVIDUALS AND FAMILIES

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I. Introduction

No one can predict how much sickness and loss of life will result if and when the next influenza pandemic occurs. Experts agree, the issue is not if it will occur, but when. Whatever that time is, such pandemic flu would likely overwhelm the capacities of our hospitals, clinics and emergency services. Most people ill with the flu will have to be cared for at home by family members and other trusted caregivers.

When threatened with a viral strain such as H5N1, having a reported case fatality rate of approximately 50%, the prospects that individual behaviors and even some policy decisions will be driven by public panic become all too real. While it is highly unlikely that the next serious human-to-human flu will have a fatality rate anywhere near 50%, the chance for panic still exists. One of our major points here is that educating the public on simple behavioral measures can replace panic with feelings of control, There are simple things that we can do – as individuals, as

families and as co-workers -- to reduce even if not eliminate the chance of becoming infected with influenza virus.

All fifty states have developed plans that detail a mix of medical and non-pharmaceutical interventions that can be phased in, if and when human to human transmission is observed and cases reach this country or a nearby region. State planners recognize that vaccines and anti-viral drugs will be unavailable or insufficient and many detail efforts that would be put in place to implement various social distancing measures. We reviewed all of these plans and believe that every one misses a huge opportunity to empower individuals and families to act on their own behalf, by taking certain steps that could well go a long way toward reducing the adverse impact of the event.

One simple example is hand washing. Health authorities, of course, strongly advise hand washing or sanitizing, thoroughly and frequently. Both common sense and available scientific evidence support these practices, as the virus often lands on the hands which then act as conduits to the body by hand-to-face contact. Unfortunately, compliance falls well short of what is needed to mitigate transmission of common respiratory viruses, let alone virulent new strains of flu. Beyond the public education campaigns to encourage this practice, there are a number of other interventions that could be adopted for use in the home. All are relatively low cost and most are easy to implement, with ongoing compliance

requiring little effort beyond the initial installation. The steps suggested are particularly important when a family finds itself caring for a sick loved one, at home, presumably in bed.

The problem? The effectiveness of these interventions is difficult to study. They don't easily lend themselves to executable designs of randomized trials, or even observational studies in which study subjects could be counted on to adhere to the protocols. But in each case, a highly plausible theory or mechanism exists to explain how the intervention would help. In this paper, we describe a set of options, in addition to hand sanitizing, and argue that a mix of these low cost, low risk practices could help slow and reduce the spread of pandemic flu.

II. Mechanisms of Influenza Virus Particle Transmission

Flu virus is initially spread by emissions from the nose and mouth of ill individuals during behaviors that include coughing, sneezing or merely talking. Virus is "shed" in particles of different sizes. Small particles, typically five microns in diameter may be emitted as aerosols which can then be carried in the atmosphere. They can remain suspended in air for long periods of time and can be moved through spaces along currents (*Collignon, 2006)*. The ability of these aerosols to produce infection is greatest when ventilation is limited, which is commonly the case in sickrooms, but also onboard airplanes and in other closed spaces. When healthy persons inhale these aerosols, the effect can be directly to infect the tissues

of the respiratory tract. In human influenza, these particles are believed to attach to the throat. (In the instance of avian flu, the particles do not attach to the throat tissue; they need to pass down and attach to the lung tissue in order to infect the individual.) This virus transmission mechanism is simple and straightforward: from infected individual, directly through the air, to a susceptible individual.

Large emission flu-laden particles, typically 10 microns in diameter, pose different kinds of risks and typically infect upper respiratory tissues such as nose, mouth and throat. These larger particles travel only short distances and settle on surfaces, but can transmit disease for periods as long as 48 hours. Healthy individuals in close proximity with flu sufferers might directly contact these large particles through the air, or they may touch surfaces on which they have settled and then infect the tissues of their mouth or nose. Also, some of the moisture contained in these large particles can evaporate, producing smaller particles called droplets that pose risks similar to those of the smaller particles described above (*Collignon, 2006; CIDRAP, 2007; Beumer, 2002*). So, in the case of large particles, the virus transmission mechanisms are two: air-to-air and also air-to-surface which leads to hands-to-face-to-infection.

The properties of these large and small particles, and presumably their ability to produce disease are affected by ambient conditions such as temperature and humidity. Also, the virus-containing particles are potentially vulnerable to a

number of interventions that include disinfectants, mechanical barriers and others that change the way they behave. Implementing these virus-affecting interventions can reduce the chance of becoming infected.

III. Hand Hygiene

Hand hygiene offers its greatest potential as a way to prevent infection by the larger virus particles, as hands are a common intermediary between infected objects, surfaces and individuals and the vulnerable entry points into a healthy person's body. Evidence from empirical studies in a variety of settings – particularly hospitals, day care centers and schools suggests the ability to reduce infections from 20 – 50% if recommended washing and sanitizing techniques are used diligently *(WHO Writing Group, 2006; Luby, 2005; Roberts, 2006; Falsey, 1999; Rabie, 2006; St. Sauver, 1998).*

Common detergent-based soaps are effective at cleaning visible dirt. Evidence suggests that the greater the time a person spends washing their hands, the more pathogens can be removed, with thirty seconds considered optimal. Alcohol-based hand sanitizers can be highly effective agents to disinfect hands due to alcohol's ability to denature virus-associated proteins. In fact, one study showed that use of a 95% ethanol-based rub brought flu virus to undetectable levels after thirty seconds of use, by which time there would be complete drying of the hands *(Centers for Disease Control and Prevention, 2002; Schurman, 1983).*

How many people can be expected to spend thirty seconds each time they wash or sanitize their hands? The CDC strongly endorses and other authorities strongly advocate hand hygiene as a key practice to reduce disease *(Centers for Disease Control, 2008; HMS Report 2007).* Soaps and sanitizers are inexpensive and their use poses minimal risks. Public education programs are strongly encouraged. But, without a massive public education campaign, such advocacy is unlikely to produce enough practice change, by itself to prevent pandemic flu transmission.

IV. Surgical Masks

Common surgical masks may block some large virus particles that are emitted when a sick person sneezes or coughs, but they probably do little to block transmission of the aerosols *(U.S. Department of Health and Human Services 2008; Press 2006).* Some evidence suggests that masks worn by infected persons reduce the speed of air coming from the mouth or nose, and thus limit the distance these large particles will travel *(Inouye, 2006).* If a healthy person wears a mask, some large particles will probably be blocked and hence, not inhaled. Possibly more significant is that a well person wearing a mask will find it much more difficult to transfer virus from the hands to the more vulnerable nose and mouth *(U.S. Department of Health and Human Services 2008; Collignon, 2006).*

We could find no reports of controlled studies of the efficacy of masks to control the spread of influenza virus. Partly, this is because masks are unlikely to be used in the absence of other hygiene and infection control measures *(World Health Organization Writing Group, 2006)*. Use of surgical masks is often required in hospital settings for health care workers and visitors having frequent and prolonged contact with sick patients. On occasion, masks have been recommended by public health officials to be worn while on public transportation, or in some crowded areas *(U.S. Department of Health and Human Services, 2008)*, but rarely, if ever within the home.

Even if wearing of masks confers only modest incremental benefits, such benefits would undoubtedly be positive; hence the practice should be strongly encouraged (*Weiss, 2007; Press, 2006)*. These masks are inexpensive and widely available and could prove useful in the home, as they could contribute to reducing the risk that a healthy family member would contract the flu from another who is sick.

V. Air Filtration and Ventilation

Imagine that you are caring for a family member infected with the flu; this family member "isolated" in a bedroom. You want to provide all the care needed and yet reduce the chance that you and other family members will become infected from the ill family member.

There is evidence to suggest that specialized air handling and ventilation are effective in reducing potential aerosol transmission of influenza *(Li, 2007)*. These measures are relatively low cost and could easily be implemented in the home. Empirical observations have been reported that increased rates of infection are strongly correlated with poorly circulated or ventilated air. High Efficiency Particulate Air (HEPA) filters, often made up of glass fibers, have the ability to remove nearly 98% of particles 0.3 microns or greater in size, which could include many containing airborne flu virus *(Sehulster, 2004)*. It turns out that increasing the efficiency of the filtration can be accomplished either by increasing the rate of air circulation through the filter or the amount of new air entering the room from outside *(Spendlove, 1983)*. Ambient conditions such as temperature and humidity also can affect the efficiency of filtration, although commercial grade filter systems operate effectively in the range of environments typically to be found in the home.

Homes that are heated with forced air or other climate control and ventilations systems can usually accommodate HEPA filters that typically cost $100 or less. For homes that are heated with hot water and other systems that do not include circulated air, a portable air purifier that contains a HEPA filter can be used. Suitable portable devices that circulate and filter the air can be purchased for $100 - $500 per unit. The benefits that accrue from filtration, in terms of preventing the spread of flu virus can be dependent on the placement of the

portable units in the rooms as well as occasional maintenance that is required of the devices and filters *(Sehulster, 2004).*

Some have argued that having an exhaust fan in a sick room also can be useful in containing the virus. Placing a fan facing outside, in the window of an enclosed patient care room creates a negative pressure differential in the room, compared to outside. This differential is presumed to reduce the leakage of infected air when the door of the sickroom is opened to other parts of the home[1]. *(Centers for Disease Control, 2008)*

VI. Ultra-Violet Light

The UV-C wavelength range of ultraviolet light has been found to be germicidal and to have the potential ability to disinfect air by inactivating virus-containing aerosols *(Weiss, 2007).* (The UV-B energy range is the part of the spectrum that is associated with the risk of developing skin malignancies; not the UV-C range.) One study conducted in a hospital examined the rate of influenza in two of its comparable buildings; only one of which had UV lights installed. The finding was a 2% rate of flu in the irradiated building, compared to 19% in the other *(Tellier, 2007).*

[1] According to CDC recommendations for hospitals, "**Airborne Precautions:** Place the patient in an airborne isolation room (AIR). Such rooms should have monitored negative air pressure in relation to corridor, with 6 to 12 air changes per hour (ACH), and exhaust air directly outside or have recirculated air filtered by a high efficiency particulate air (HEPA) filter." (21)

UV light could be particularly useful in the home, and some other studies have found it to work best when people are exposed to it for extended periods of time *(Weiss, 2007)*. As with other interventions, the placement of the lights and ambient conditions such as relative humidity will affect its germicidal capability, with lower levels of humidity seem to be preferable *(Spendlove, 1983; Tellier, 2007)*. Effectiveness of irradiation can double when there is a continuous source of cold air at the ceiling level. The cold air will naturally move downwards as warmer air moves upwards, allowing more air circulation and in turn, more exposure to the UV irradiation. A large room fan could also support this effect *(Spendlove, 1983)*. To most efficiently process the expulsion of infected material from a cough, for example, given the elapsed time until the virus particles make their way to the germicidal light source, a continuous process that incorporates proper air circulation, pressurization and filtration would be highly desirable *(Weiss, 2007; Sehulster, 2004)*. Two fans may be best: one for exhausting to outside, to create negative air pressure, the other within the room to promote in-room circulation.

Ultra violet light units suitable for virus removal in home use can be purchased in the range of $150. Some units contain air circulation systems with HEPA filters. More expensive systems that require professional installation within duct systems and ceiling fixtures and routine maintenance are also available.

VII. Controlling Temperature and Humidity

Recently published research suggests that higher levels of temperature and relative humidity are both associated with reduced virus flu transmission. These studies, conducted in animal models suggest that higher temperatures and more humid air are both consistent with stronger and more effective host immune defenses, particularly in the early stages of developing an infection. The same research also finds at higher levels of humidity, the virus aerosols are less stable, and the larger particles absorb moisture, increase in size and then settle out of the air *(Lowen, 2007).* This research was done independently of the research that led to recommendations about HEPA filters, UV light, in-room air circulation and negative air pressure. In a home, the person setting up the bedroom of the flu-infected loved one would have to decide which route to take: air circulation with filters, negative air pressure and UV light (which are reported to work best with low moisture content of the air), or heat and high humidity.

In the home, the temperature of the room can typically be regulated with the thermostat, while desired levels of humidity can be achieved by use of portable humidifiers that can be purchased for $25 - $50.

VIII. "Family Friendly" Packages

We propose that state or local health officials could develop "family friendly" packages that could be offered as examples of actions that individuals can take in their own behalf to prepare for a flu pandemic. A key ingredient would be the

development of a "fact sheet" that is written in plain English and offers details of how to use each option in the set. A public information campaign would announce and publicize the program, with participation of local print and electronic media. Organizations analogous to those that perform audits of private homes to recommend ways to reduce energy consumption could be established to assist families implement these options correctly. Possibly, subsidies can be arranged from prominent employers, local merchants and some government funding.

IX. Benefits, Risks and Costs

Our proposal goes well beyond existing guides and checklists that advise individuals and families how to prepare for pandemics (see pandemicflu.gov). Such checklists already include hand hygiene (and occasionally wearing of surgical masks), identify specific foods and supplies to have on hand, and suggest other behaviors to minimize close interpersonal contact.

Of particular interest in our proposed extension of existing practices is a small set of hardware-embodied interventions. A homeowner would not necessarily need to adopt all of these. (In fact, some might be incompatible with one another as the ambient conditions in which they work best are opposite.) A suitable air filter, exhaust fan, humidifier and ultraviolet light are interventions that can easily be implemented in the home and from which families could benefit passively after a modest initial investment of time and money. As shown in Table 1, the budget for a

full set of these items can be as low as $250. We expect that the potential benefits, in terms of reducing spread of virus would turn out to be quite high, even if they are difficult to quantify specifically.

The level of evidence of efficacy of each of these practices in reducing disease does not rise to that of randomized trials or observational studies. When faced with decisions to prescribe medications or undertake invasive clinical procedures, medical professionals would properly demand strong evidence of efficacy before advocating their adoption. But the interventions we are proposing are not therapies, but rather effect environmental changes that do not appear to pose measurable risks. For each measure there is an associated, plausible rationale to explain how it would help. And the cost of implementing each intervention is sufficiently low that only a modest level of incremental benefit should be required for many individuals and families to choose to do so.

If and when a pandemic occurs, we will need every incremental benefit that can be accrued! Seemingly small steps could literally mean the difference between life and death.

X. Conclusion

No one can accurately predict when the next flu pandemic will come. As vaccines and antiviral medicines will, at best, offer only limited protection, public

health officials, employers, universities and others have developed plans that encompass a number of non-pharmaceutical interventions – recommended changes in behavior intended to reduce the spread of disease.

We are not the only ones suggesting that existing pandemic plans fail to go far enough in encouraging changes in individual behaviors to reduce the spread of disease *(Brown, 2008)*. But, we have suggested specific ways to arm families with low-tech interventions that can be easily implemented in the home and could prove to be valuable measures in preventing illness. Even if a pandemic does not occur anytime soon, we argue that such common sense measures would help to create an environment within the home that is less conducive to the spread of viral illness and would also have applicability in preventing commonly and seasonally occurring infectious diseases.

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References

Avian Influenza (Bird Flu): Implications for Human Disease. Center for Infectious Disease Research and Policy (CIDRAP), University of Minnesota. Available at: http://www.cidrap.umn.edu/idsa/influenza/avianflu/biofacts/avflu_human.html, Accessed July 2007.

Beumer R., Bloomfield S., Exner M., Fara G., Nath K.J., Scott E. The infection potential in the domestic setting and the role of hygiene practice in reducing infection. International Scientific Forum on Home Hygiene, August 2002.

Bird Flu. How to understand your risk and protect your health. Harvard Medical School special report, 2007.

Bloomfield, S., A.E. Aiela, B. Cookson, C.O'Boyle, E.L. Larson. The effectiveness of hand hygiene procedures in reducing the risks of infections in home and community settings including handwashing and alcohol-based hand sanitizers. American Journal of Infection Control, Vol. 25, No. 10, pp. S27-S64, Decembr 2007. http://www.ajicjournal.org/article/PIIS0196655307005950/fulltext.

Brown, D., CDC Issues Guidelines For Battling Flu Pandemic**,** School Closings Likely, but Restricting Travel Not Suggested. *Washington Post*, February 2, 2007, p. A03. Assessed February 17, 2008. http://www.washingtonpost.com/wp-dyn/content/article/2007/02/01/AR2007020100850.html.

Centers for Disease Control and Prevention. Guideline for hand hygiene in healthcare settings: recommendations of the healthcare infection control practices advisory committee and the HICPAC/SHEA/APIC/IDSA hand hygiene task force. MMWR 2002; 51: [inclusive page numbers].

Centers for Disease Control and Prevention. Outbreak Prevention and Response Protocol General Information on Hand Hygiene, Available at: http://www.cdc.gov/nceh/vsp/cruiselines/hand_hygiene_general.htm, Accessed January 2008.

Centers for Disease Control, Interim Recommendations for Infection Control in Health-Care Facilities Caring for Patients with Known or Suspected Avian Influenza, May 21, 2004. Accessed February 16, 2008.

Collignon P.J., Carnie J.A. Infection control and pandemic influenza. Medical Journal of Australia. 2006; 185: S54-S57.

Falsey A.R., Criddle M.M., Kolassa J.E., McCann R.M., Brower C.A., Hall W.J.. Evaluation of a handwashing intervention to reduce respiratory illness rates in senior day-care centers. Infection Control and Hospital Epidemiology. 1999; 20: 200-202.

Inouye S., Matsudaira Y., Sugihara Y. Masks for influenza patients: measurements of airflow from the mouth. Japanese Journal of Infectious Disease. 2006; 59: 179-181.

Interim public health guidance for the use of facemasks and respirators in non-occupational community settings during an influenza pandemic. U.S. Department of Health and Human Services Pandemic Influenza Website. Available at: http://www.pandemicflu.gov/vaccine/mask.html/, Accessed March 5, 2008.

Li Y., Leung G.M., Tang J.W. et al. Role of ventilation in airborne transmission of infectious agents in the built environment- a multidisciplinary systematic review. Indoor air. 2007; 17: 2-18.

Lowen A.C., Mubareka S., Steel J., Palese P. Influenza Virus Transmission is Dependent on Relative Humidity and Temperature. PLoS Pathog. 2007; 3(10): e151. Doi:10.1371/journal.ppat.0030151.

Luby S.P., Agboatwalla M., Feikin D.R., Painter J., Billhimer W., Altaf A., Hoekstra R.M. Effect of handwashing on child health: a randomized controlled trial. The Lancet. 2005; 366: 225-233.

Press D., Toner E.. CBN Report: Contraty to Prevailing Beliefs, Aerosol may be Significant Mode of Flu Transmission, Clinician's Biosecurity Network, (http://www.upmc-cbn.org/report_archive/2006/09_September_2006/cbnreport_092806.html), 2006.

Rabie T., Curtis V. Handwashing and risk of respiratory infections: a quantitative systematic review. Tropical Medicine and International Health. 2006; 11: 258-267.

Roberts L., Smith W, Jorm L., Patel M., Douglas R. M., McGilchrist, C. Effect of infection control measures on the frequency of upper respiratory infection in child care: a randomized, controlled trial. Pediatrics. 2000; 105: 738-742.

Saint Sauver, J., Khurana M, Kao A., Foxman, B. Hygenic practices and acute respiratory illness in family and group day care homes. Public Health Reports. 1998; 113: 544-551.

Schurman, W. and Eggers H. Antiviral activity of an alcoholic hand disinfectant: comparison of in vitro suspension test with in vivo experiments on hands and on individual fingertips, Antiviral Res. 1983; 3:25-41.

Sehulster L.M., Chinn R.Y.W., Arduino M.J. et al. Guidelines for environmental infection control in health care facilities. Recommendations from CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). Chicago IL; American Society for healthcare Engineering/American Hospital Association, 2004.

Spendlove J.C., Fannin K.F. Source, significance and control of indoor microbial aerosols: human health aspects. Public Health Reports. 1983; 98: 229-244.

Tellier, R. Review of Aerosol Transmission of Influenza A Virus. Emerging Infectious Diseases [serial online], November 2006. Available at: http://www.cdc.gov/ncidod/EID/vol12no11/06-0426.htm, Accessed August 2007.

Weiss M.M., Weiss P.D., Weiss D.E., Weiss J.B. Disrupting the transmission of influenza A: face masks and ultraviolet light as control measures. American Journal of Public Health. 2007; 97: S32-S36.

World Health Organization Writing Group. Nonpharmaceutical interventions for pandemic influenza, national and community measures. Emerging Infectious Disease [serial online]; 12. Available at: http://www.cdc.gov/ncidod/EID/vol12no01/05-1371_app2.htm, 2006.

Table 1. Check List.

Things to get:	**Typical Cost**
Detergent-based soap	$10
Alcohol-based hand sanitizer	$10
Window fan	$40
Ultra Violet light unit (some with HEPA filters)	$180 - $370
High Efficiency Particulate Air (HEPA) filter system	0 - $600
Face masks (25)	$10
	TOTAL $250 - $1,000

Things to do and not to do:

Don't shake hands with people.
Cough into your elbow.
Wash hands frequently with hot soap and water, at least 30 seconds and dry.
Try not to touch your face with your hands.
Try to avoid direct hand contact with surfaces that are likely to be contaminated.
Hold meetings via telephone and email when possible.
Read and study http://www.ifh-homehygiene.org/2003/index.html